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PHYSICAL CONSTRAINTS TO URBAN DEVELOPMENT IN NINETEEN SELECTED AREAS IN MISSOURI

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CONTENTS

INTRODUCTION

Regional geologic appraisals of 19 selected growth areas within Missouri are presented in this report. Topics discussed include: landforms and relief, rock and soil formations, earthquake potential, scenic natural resources, mineral resources, water resources and land use.

Landforms and Relief. A description of the geologic and physiographic factors, including landforms, relief, drainage development, slope categories, karst topography and floodplains.

Rock and Soil Formations. A description of the bedrock types, surficial materials and soil thicknesses found in each study area.

Earthquake Potential. A description of the structural features of the study area, such as folds and faults. Potential earthquake activity is also included.

Scenic Natural Resources. An accounting of the area's known caves, springs, natural bridges and other scenic geologic features.

Mineral Resources. A summary of the known mineral resources and their relationship to the development of the area, especially in the context of sequential use.

Water Resources. An analysis of the surface water, including quality and volume (in impoundments), or discharge (flow), and groundwater resources available, including producing formations, their expected yields, recharge areas and water quality. Also included is an overall evaluation of the relationship between surface and groundwater supplies, potential for pollution, and procedures necessary to prevent pollution.

Land Use. A summary of the physical characteristics of bedrock and unconsolidated materials and an evaluation of their relationship to solid- and liquid-waste disposal, water impoundment, and other facilities or structures related to development. Suitability of the various slope categories and floodplains for development is discussed also.

The regions discussed within this report are numbered, beginning in the northwest with Nodaway County and ending in the southeast with Butler County. Information is based on published and unpublished reports on file at the Missouri Geological Survey and Water Resources and on the field experience of Survey staff members.

This report is intended to serve both the non-geologist and geologist by explaining in non-technical terms the physical elements and problems associated with proper land use and resource development. Suggestions are offered concerning methods of reducing or eliminating these problems. However, this report cannot furnish all the geologic information needed for such development, and it is recommended that thorough geologic and engineering investigations be conducted before any land is put to use.

ACKNOWLEDGEMENTS

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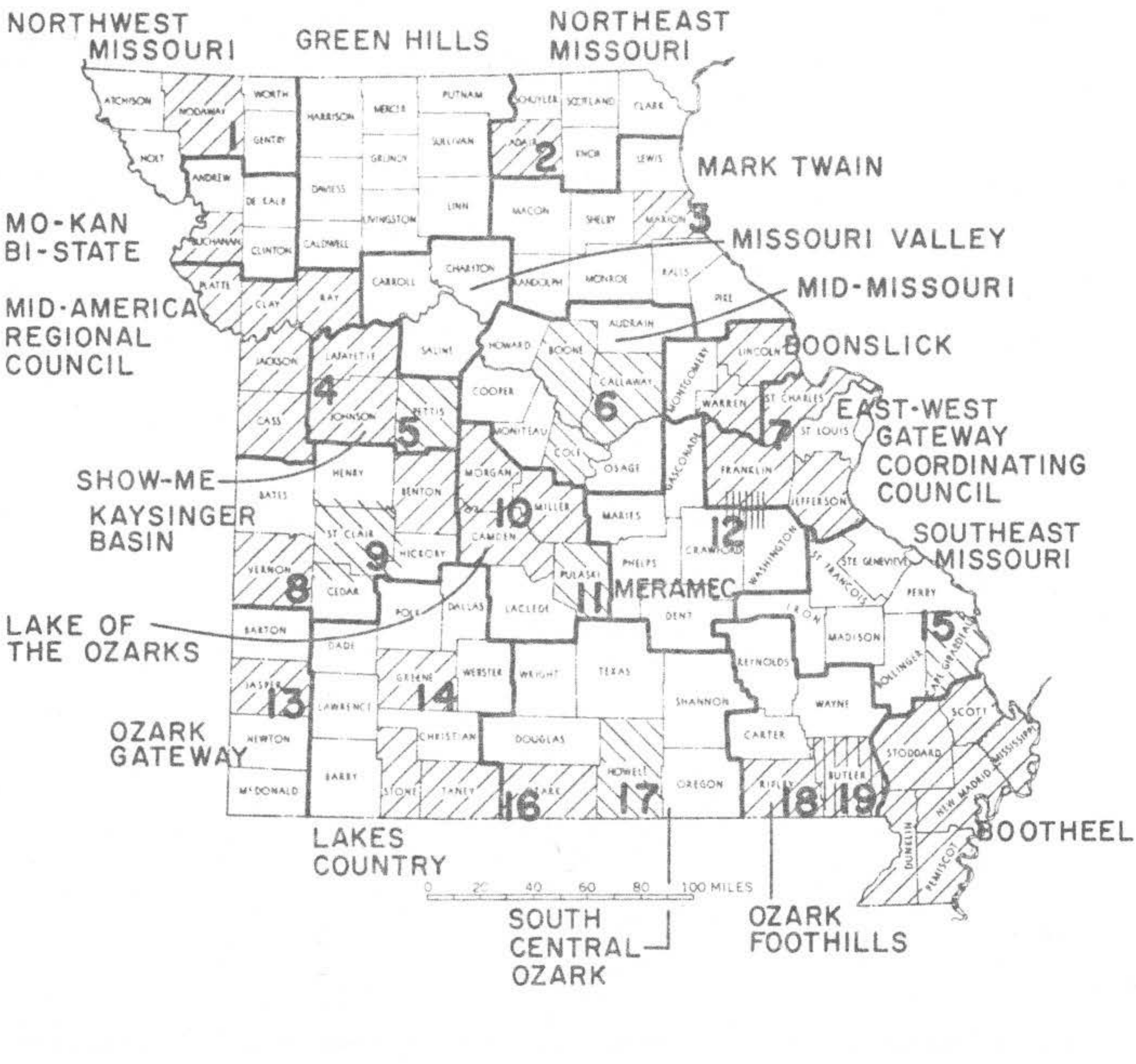

Fig. 1. Numbered cross-hatched areas are covered in this report.

SUMMARY OF MINERAL AND WATER RESOURCES

SUMMARY OF MINERAL AND WATER RESOURCES

RESOURCES / AREAS	CHAPTER	IRON ORE: SURFACE HEMATITE AND LIMONITE	IRON ORE: MAGNETITE AND HEMATITE	LEAD	ZINC	BARITE	COAL	OIL	GAS	STONE: CRUSHED AND BROKEN	STONE: DIMENSION	SAND AND GRAVEL	SILICA SAND	CLAY: STRUCTURAL	CLAY: REFRACTORY	GROUNDWATER: AVERAGE QUALITY	GROUNDWATER: RESOURCES (PRESENT)	GROUNDWATER: RESOURCES (FUTURE)	SURFACE WATER: AVERAGE QUALITY	SURFACE WATER: RESOURCES (PRESENT)	SURFACE WATER: RESOURCES (FUTURE)
NODAWAY CO.	1						S/KS	P	P	M/KS		S/KS		P		V	2	2	G	2	3
ADAIR CO.	2						M/KM	P		S/KS		S/KS		P		V	2	2	G	2	2
MARION CO.	3			P	P			P		S/KL	P	M/KL				V	3	3	P	3	3
KANSAS CITY - ST. JOSEPH AREA	4						L/KL	S/KS	S/KS	L/KM	S/P	L/KL		M/KL		V	2	2	P	3	3
PETTIS CO.	5			N/KN	N/KN	S/P	S/KS			M/KL	P		KS	P		V	2	2	V	1	2
BOONE, CALLAWAY, AND COLE COS.	6	KS		S/KN	S/KN	S/KM	L/KL			L/KL	P	L/KL	S/KN	S/KS	L/KM	G	2	3	V	3	3
ST. CHARLES AREA	7		P				N/	P		L/KL	P	S/KL	L/KL	S/KS	S/KS	V	3	3	P	3	3
VERNON CO.	8						S/KL	L/KL	N	S/KS				KL		V	2	2	V	2	2
ST. CLAIR CO. AREA	9	KN		N/KN	N/KN	S/KS	L/KL			M/KL	P	S/KM		S/KM		G	2	2	V	2	3
LAKE OF THE OZARKS	10	S/KS		S/KN	S/KN	M/KM				M/KL	P	M/KM			S/KS	G	3	3	V	3	3

PULASKI CO.	11	S/KS								**S/KM**	P	**M/KM**				G	2	2	G	3	3
MERAMEC PARK LAKE AREA	12	M/KM	**L/KL**	S/P	S/P	S/KN				S/KL	S/KS	**M/KL**			S/KS	G	2	2	G	2	3
JASPER CO.	13			M/KS	L/KM		S/KS			**L/KL**	**L/KL**			P		V	2	2	V	2	2
GREENE CO.	14	KS		S/P	S/P					**L/KL**	**M/KM**			P		V	2	2	V	2	2
CAPE GIRARDEAU CO.	15									**L/KL**	P	**M/KL**	KL	**M/KM**		V	2	3	P	3	3
OZARK, STONE, AND TANEY COS.	16	M/KS			S/P					**S/KL**	P	**S/KS**				G	2	2	G	3	3
HOWELL CO.	17	M/KM	P		P					**S/KM**	P	**S/KS**				G	2	3	G	1	2
BOOTHEEL AREA	18		P					P	P	**M/KS**	P	**M/KL**		**M/KM**		G	3	3	P	3	3
BUTLER CO.	19	M/KS								S/KS		**S/KM**		**N/KN**		G	2	3	G	2	3

LEGEND

MINERAL RESOURCES

PRODUCTION STATUS

CURRENT PRODUCTION

PAST PRODUCTION

PRODUCTION / RESOURCE POTENTIAL

RESOURCE POTENTIAL

K KNOWN
P POSSIBLE

AMOUNT &/OR SIZE

L LARGE
M MEDIUM
S SMALL
N NEGLIGIBLE

WATER RESOURCES

QUALITY

G GOOD
V VARIABLE (Varies with aquifer chosen)
P POOR

PRODUCTION

1 INADEQUATE
2 ADEQUATE
3 PLENTIFUL

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NODAWAY COUNTY, NORTHWEST REGION

Summary

Nodaway County lies within a region of moderately dissected plains. Maximum relief within the county is about 110 feet.

The bedrock formations consist of limestone and shale. Covering the bedrock surface are deposits of glacial till and loess. These units (bedrock, till and loess) have weathered to form a thick, silty clay soil.

Nodaway County is not considered to be in danger of earthquake activity.

The known mineral resources of Nodaway County are limestone, sand and gravel, shale and coal. Limestone and sand and gravel are the only commodities presently produced. Reserves are not believed large.

Water resources are obtained from both surface water and groundwater. Surface water collected in impoundments is potentially the best source of clean water. Currently the county's supply of water is derived from groundwater. Alluvial gravels produce water of superior quality. The major drawback to this water is its high iron content, which must be removed by treatment. Locally the water may also be high in chlorides and dissolved solids. Yields of wells in the alluvium vary from less than 100 to 500 gallons per minute. Wells in glacial drift produce water which is high in sulfates, iron and dissolved solids. This water must be chemically treated before it can be used. Yields of individual wells may exceed 50 gpm. Wells drilled in bedrock produce water of inferior quality.

Proper land use in Nodaway County will require on-site investigation at proposed development sites to insure that both bedrock and soil are capable of withstanding the load to be placed on them. Excellent sites are available for constructing waste-disposal facilities such as sewage lagoons and sanitary landfills. Utilization of septic tanks and treatment plants will be more difficult because of soil limitations and variabilities of stream flow. Few difficulties will be encountered in lake and road construction.

Problems encountered in Nodaway County dealing with resources and waste disposal are not limited by political boundaries and therefore extend into the surrounding five counties.

This report is intended to serve as a regional appraisal of the geologic features, resources and problems of Nodaway County. It is not intended to supply all the answers needed for proper geologically oriented development, but to serve as a guide. Careful on-site investigation is recommended in all cases to insure proper regional planning.

Landforms and Relief

Nodaway County lies within an area dominated by moderately dissected plains. Major streams within this area flow either northerly or southerly creating very elongate, low-profile hills. The valley of the Hundred and Two River is from 1 to 2 miles wide. Other floodplains within the area are generally less than one fourth mile wide. Relief throughout the area is usually 75 to 110 feet.

Rock and Soil Formations

Bedrock formations consist of alternating (or cyclical) beds of limestone and shale. The limestones are generally chert-free and the shales are clayey and may be carbonaceous. Coal is present and has been mined in the past. The entire area has been glaciated and covered by till. Over the till may be a thin (10-20 feet) mantle of loess. Soil cover has been developed over the entire county, and the kinds of soil present reflect the character of the parent bedrock, till, or loess. In most cases the soil is a silty clay mixed with stones. Thickness of this soil is often greater than 40 feet.

Earthquake Potential

Bedrock in Nodaway County is for the most part flat-lying, except in those areas where structural deformation has occurred in the distant past. Two major structures are within the area. The Hamilton-King City-Quitman anticline in southwestern Nodaway County is a large, gentle fold. The Forest City structure is a large basinal area in the northwest corner of Missouri; the bedrock layers here dip 40 minutes to the northwest. Nodaway County is not considered to be in danger of earthquake activity.

Scenic Natural Resources

There are no known caves or big springs within Nodaway County.

Mineral Resources

Active mineral production in Nodaway County is limited to limestone and sand and gravel.

Stone. Resources of limestone are not large. Units present are thin and covered with thick deposits of glacial drift. Principal uses are in construction and aglime.

Sand and Gravel. Sand and gravel are produced from alluvial and upland glacial deposits. Production is mostly sand and used in building. Reserves are not believed large, and additional study is needed to determine future potential. Large deposits of sand and possibly gravel could be present in the glacial till.

Shales. Shales probably suitable for the manufacture of structural clay products are present over wide areas. However, little data is available on their potential.

Fuels. Known reserves of coal are small in Nodaway County. The major coal-bearing horizons lie deep beneath the surface, and only a few thin beds occur at the surfaces. Oil and gas are present in small amounts in several areas of northwestern Missouri. Although none is known in Nodaway County, some possibility for their presence does exist.

Water Resources

Water supplies are obtainable from surface impoundments, from the streams, from the alluvial fill in stream valleys, and from the glacial drift materials.

Surface Water. Impoundments are potentially the source of water having the best chemical characteristics as compared to other sources. The normal engineering guides should be followed in the site selection and in the design of the structure and water-treatment facilities. Treatment is primarily for making the water safe biologically. Turbidity is another quality parameter which must be improved by treatment. Water from this source is generally low in total dissolved solids and is soft. The volume of water which can be made available by impoundments can be ample to meet all anticipated needs well through the year 2000.

Low-flow characteristics of the three major streams, which are Nodaway, Hundred and Two, and Platte, leave much to be desired. Summer and fall flow are poorly maintained by groundwater discharge. During drought conditions water supplies derived from streams may not be sufficient. Water quality is variable from one point to another along an individual stream. This quality also varies with the seasons. Generally, with treatment, the resultant water meets public health standards for permissible maximums. Generally it is more desirable to develop a water supply from the alluvial fill of these same stream valleys rather than taking the water directly from the rivers.

Groundwater. Stream-valley alluvium generally produces water having superior qualities to that of glacial drift or of the bedrock formations. Generally, but not at all sites, the alluvium produces water which meets public health standards. An exception is iron. Iron levels are generally high and must be lowered by chemical treatment. Locally, where chemical characteristics are such that they do not meet health standards, there has been leakage from the underlying glacial drift materials or from bedrock. This leakage results in groundwater having high sulfates, perhaps high chlorides, high total dissolved solids, and considerable hardness. Test pumping to establish productivity of a given site and chemical testing of the water from each site is essential. Generally this alluvial material is less than 50 feet thick. Yield capabilities, to an individual well, may run up to as much as 500 gallons per minute. More common, though, are yields of less than 100 gallons per minute. Recharge is principally from the streams. Because of the alluvium's storage capacity it is less affected by drought than the streams, but supplies may be less than sufficient in periods of drought.

Two major glacial-drift-filled channels dissect the county. One of these channels, entering from Iowa three miles east of Braddyville, Iowa, extends southward near Maryville, where its direction becomes more east-southeast. It leaves the county to the east of Conception Junction. The other major channel extends along the border between Nodaway County and Andrew County. In places, this drift fill may exceed 350 feet in thickness. The total thickness of clean sands and gravels may exceed 100 feet. Yields in excess of 500 gallons per minute are obtainable from these thick, clean sands. It is imperative that test drilling be carried out prior to the commitment of the monies for the drilling of a production well or for the construction of a water system. Not all sites, even within the most favorable reaches, are productive. The reasons are multiple, with the lack of clean sand being the most prevalent.

Recharge does occur, but in a restricted manner as compared to the alluvial materials of the stream valleys. Using projection of anticipated water needs, over-withdrawals are not anticipated. Marginal to these drift-filled valleys, with the thinning of the drift, the potential for water production decreases and may be incapable of supplying sufficient water to meet the needs of a rural home. It is the practice to establish the productivity by a test hole prior to the actual construction of the well. The quality of the water from glacial drift sources generally does not meet public health standards for public water supplies. Generally the levels of sulfates, iron and total dissolved solids are high. The water is hard.

Those areas not having water-productive alluvium or glacial drift have only the bedrock formations which are productive of groundwater. Almost without exception, the chemical quality of groundwater from the rock formations is very poor. In addition to excessive amounts of sulfates and total dissolved solids, chlorides are generally excessive. Total dissolved solids may exceed 10,000 parts per million in wells having depths of 450 feet or less. This water would be judged as unsuitable even for livestock. Almost without exception, the water from this source would be unsuitable for domestic needs. Generally it is advisable in these areas to develop the water supply by surface impoundments.

Land Use

In order to insure proper land use, it is necessary that several things be known. These include strength of bedrock and soil present in the area and their relationship to the area's water resources. Two engineering geology units are present in Nodaway County.

Unit One - Thick Glacial Soil (G1)

This unit encompasses most of Nodaway County, except for those areas occupied by the major streams. The soil is a silty-clay type, mixed with stones. The thickness, which is usually about 40 feet in the south, becomes greater in the north.

Sewage Lagoons. The use of sewage lagoons within this unit is favorable. No problems are anticipated in those areas where the soil is very clayey. Problems with leakage will be encountered where the soil is silty, but with the use of sealants, such as bentonite, the site can be successfully used. The effluent from these lagoons should not be allowed to seep into silt areas because of rapid percolation into the subsurface. Serious problems with water pollution can result if the effluent is not sufficiently treated before discharge.

Septic Tanks. The use of septic tanks in this unit should be limited because of unfavorable silty clays. Rapid downward percolation of effluent will result in its not being filtered or oxidized, and this untreated water can pollute the groundwater supply. In areas where shallow soils are present over limestone or shale bedrock, a heavy clay is usually formed on their common surface. This impermeable interface will cause the sewage effluent to resurface, and this will result in surface pollution. Septic tanks can be used in areas of low population density.

Sewage Treatment Plants. These can be utilized in most of the county. The major problem will be in finding an acceptable discharge point. Streams with persistent flow (needed for proper dilution) include the Nodaway, One Hundred and Two, and Platte Rivers.

Sanitary Landfills. Excellent sites for sanitary landfills can be found with little difficulty. The rugged hills present in Nodaway County are generally covered with thick silt deposits. Because the gullies between those hills are small, problems encountered with surface runoff are significantly reduced. Although the silts are permeable, there are often thin clay seams that will act as barriers to seeping leachates. Borrow material is plentiful. Where soils are thin, the amount of soil available for cover material and flooring is often inadequate, and the site will need improvements before it can be used. Clay padding can be used to increase the impermeability of the landfill floor to prevent leachate escape. Suitability of landfill sites will generally depend on the amount of clay present in the soil.

Impoundments. Farm ponds and lakes can be successfully constructed. Good water retention can be expected in gully sites because of thicker silts and clay seams.

Construction. Problems encountered include slope failures on hillsides or road cuts and freeze-thaw breakup of roads. In some areas, problems arise from swelling subsoil clay and poor drainage.

Unit Two - Alluvial Soil (Al)

This unit is located in the valleys of the major streams. Thickness of the alluvium in the Nodaway, Platte, and Hundred and Two River valleys is 20 to 60 feet. This alluvium consists of gravel, sand, silt, and clay.

Sewage Lagoons. Several problems will be encountered. Flooding is frequent, and levees must be constructed to protect the lagoon. Material used to build the levees should not come from the lagoon site. Deepening of the levee to obtain construction materials could expose permeable subsoils and cause groundwater pollution problems, at least during time of high water.

Septic Tanks. Septic tanks should be used only on farms or widely scattered homes.

Sewage Treatment Plants. Few problems are anticipated. Low water levels during the summer months (or during droughts) may result in inadequate dilution.

Sanitary Landfills. Land in the alluvial valleys should not be utilized for landfill sites. Flooding is frequent, and soils are highly permeable. The major reason for discouraging development of sanitary landfills is that these alluvial valleys are excellent sources of groundwater and therefore should not be tampered with. Excellent sites for landfills can be found nearby in the upland plains areas.

Impoundments. Few problems will be encountered with small impoundments. Lakes and large ponds may have leakage problems and are more susceptible to damage by flooding.

Construction. Problems encountered include variable permeability and strength, flooding, and a high water table.

* * * For additional geologic information concerning Nodaway County see these selected references: 3, 6, 7, 8, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21.

ADAIR COUNTY, NORTHEAST REGION

Summary

Adair County lies in an area of low relief. Rolling plains are found in the west and smooth plains in the east. Relief is seldom more than 100 feet.

Bedrock consists of limestone and shale overlain by glacial deposits. Soils have developed over both the bedrock and glacial materials, and their thickness is quite variable. These soil deposits are usually never more than 40 feet thick but may be thinner locally and consist primarily of silty clay.

The mineral resources of Adair County are limestone, sand and gravel, shale and coal. Crushed stone is the only commodity presently produced, with sand and gravel production being intermittent. Production of both is small, and reserves are small and of low quality.

Water is obtained from both surface-water impoundments and alluvial aquifers. Increasing water needs of the county can be met by utilization of surface impoundments. Acceptable groundwater can be obtained from both glacial drift and alluvium.

Land used for waste disposal will require on-site investigation by a geologist. Information ascertained by these investigations will be needed to prevent site-failures and water pollution. In general, suitable sites can be located for sewage lagoons, sanitary landfills, and treatment plants.

Potential geologic problems similar to those encountered in Adair County will also be encountered in the surrounding seven county area.

This report is intended to serve as a regional appraisal of the geologic features, resources, and problems of Adair County. It is not intended that this report will furnish all the information needed for geologically oriented development within the county. Careful on-site investigation is recommended before any site is developed.

Landforms and Relief

Adair County lies within a plains region. The eastern part of the county is dominated by smooth plains, while the western portion is dominated by moderately dissected plains. Relief is commonly 90 to 125 feet. The floodplain of the principal river (Chariton) is from one-third to one mile wide. Slopes are steeper in the western part of the county.

Rock and Soil Formations

Bedrock formations consist of alternating limestone and shale beds, with some coal beds present also. Most of the county is covered with either glacial drift or loess (wind-blown silt), and bedrock, therefore, is not well exposed except on steep hillsides. Soil thicknesses vary from less than 40 feet in central and northwestern Adair County to more than 40 feet in the eastern and southwestern portions of the county. The soil is a silty clay, mixed with stones.

Earthquake Potential

The Kirksville-Mendota anticline is the only mapped structural feature in Adair County. The axis of this anticline (upraised fold) extends northwest from Kirksville, toward Mendota in Putnam County. The area is not prone to earthquake activity.

Scenic Natural Resources

There are no known caves or big springs located in Adair County.

Mineral Resources

Stone. Present production of mineral resources is limited to crushed stone. Principal uses are for construction aggregates and aglime. Reserves are small, present in thin beds, and often covered with thick glacial drift. Considerable stone is trucked into the county from quarries in adjacent Knox and Scotland Counties.

Sand and Gravel. Intermittent sand and gravel production is reported from the Chariton River. Deposits generally contain little gravel and are of low quality.

Shale. Shales suitable for the manufacture of structural clay products are present in several areas. There is no present production, and their future potential is unknown.

Fuels. Significant resources of coal are present in the western half of the county. Future production would seem limited to the development of small mines supplying local needs. There is some chance of small oil and gas deposits being present in Adair County along the Kirksville-Mendota anticline and nearby Lincoln fold.

Water Resources

Kirksville, the principal city in Adair County, uses a surface impoundment as a source of water. The towns of Danforth and Brashear have alluvial wells.

Surface Water. Increasing water needs of the county's growth areas can best be met by surface impoundments. Proper planning assures that the volume will be ample for these needs. The quality of this water is much superior to that from other sources.

Chariton and Salt Rivers are the principal streams in the county. Low-flow characteristics of these two streams make them unsuitable as a water source, particularly during periods of drought. The chemical quality of this water meets public health standards.

Groundwater. Alluvial fill in the valleys of the two named rivers is sufficiently water-productive that utilization could be of considerable significance. Thicknesses of this alluvial fill range upward to slightly more than 50 feet. Maximum yields are probably about 100 gallons per minute. Well sites should be selected only after exploration. Recharge is from the river, and aquifer storage generally is capable of supplying water needs through drought periods. Since iron is present in amounts greater than permissible, its removal is mandatory. With this beneficiation, the quality of the water will meet public-health standards. It is not, however, of as high quality as water from surface impoundments.

The east half of Adair County has glacial drift thicknesses ranging from about 100 feet to in excess of 200 feet. In many parts of this area, the drift has an ample thickness of clean sand which should be water productive. For reasons unknown, not all of this clean sand is water productive. At different sites, skilled water-well drilling contractors were unable to develop wells in it which were water productive. Where water is obtainable it is generally potable. Sulfates, total dissolved solids, and total hardness are all high, but not to the point of precluding the waters use. There are marked exceptions to this generalization. Some wells which have been constructed in the glacial drift have encountered water which was totally unusable. The water from these wells can be described as having odors and tastes which are unacceptable. In addition, these unacceptable chemical constituents far exceed what is acceptable for home use. For the west half of the county, drift is not present in amounts which permit it to be a source of water.

In the west half of the county groundwater must be obtained from the bedrock formations. The high mineral content of this water precludes it being suitable for home use. It is not always suitable or usable for livestock needs. Especially in the west half of the county, but also elsewhere, suitable water for rural needs can best be obtained from ponds. This water, with treatment consisting of filtration and chlorination, is generally satisfactory and has excellent chemical characteristics.

To meet growth needs, careful planning is essential for developing water supplies which are ample to meet the needs. These needs, in all probability, will be met by surface impoundments.

Land Use

Proper and successful land use can only be realized by understanding the problems that will be encountered. A knowledge of the physical characteristics and capacities of bedrock and soil is necessary. There are three engineering geology units in Adair County. These units are those designated by Hoffman (1973).

Unit One - Thick Glacial Soil (G1)

This unit is located in eastern and southwestern Adair County. The glacial soil consists of silty clay mixed with stones. Pockets and lenses of water-bearing sand are present. Thin layers of impermeable clay soil are also present. Thickness of the soil varies from 40 to 150 feet.

Sewage Lagoons. Suitable sites can be located without much difficulty. The clay-rich soils provide a good barrier to downward-seeping effluent. In those areas where the clay soil is too silty, it might be possible to decrease permeability by using a sealant such as bentonite. The use of sewage lagoons is not recommended in areas where bedrock is exposed or excavation of bedrock will be necessary. Flash floods in valleys will cause problems if not anticipated.

Septic Tanks. Septic tanks should not be used in urban or suburban settings. The clay-rich soils causes surfacing of septic-tank effluent during seasons of high rainfall. Septic tanks should be used only on farms, where polluted waters can be somewhat controlled if surfacing occurs.

Sewage Treatment Plants. No major problems are anticipated. There is little loss of river water to bedrock in this area. The problem that will be encountered most often will be that, during periods of low rainfall, discharge of treated effluent might have to be curtailed or reduced because of inadequate dilution.

Sanitary Landfills. There are few major problems in locating a good site for a sanitary landfill. Areas where gravel or a gravelly-silt zone are present should be avoided because of the danger of flash flooding. It is necessary to either divert this flow or construct a barrier around the fill sites.

Impoundments. The same restrictions regarding sewage lagoons apply here.

Construction. Problems encountered include poor drainage, slope failure, and freeze-thaw breakup of roads.

Unit Two - Thin Glacial Soil Over Cyclic Bedrock (Gl-Cy)

This unit is located in central and northwestern Adair County. The thin (less than 40 feet) glacial soil is a stony, silty clay. Exposed bedrock is usually limestone or shale.

Sewage Lagoons. Much of this area is suitable for lagoons. However, lagoons which require excavation into hillside or bedrock should be avoided. Slope failure and/or leakage of effluent to bedrock will occur.

Septic Tanks. Septic tanks should not be used in this area. Poor soil conditions (high permeability and insufficient thickness) are not conducive to good filtration of effluent. In areas where the soil is very thin, surface pollution will occur.

Sewage Treatment Plants. There are no major problems anticipated. There is little loss of stream water to bedrock. The major streams, the Chariton River and North Fork, and several smaller streams have sustained flow through most of the year. During periods of low rainfall there may be periods of inadequate dilution.

Sanitary Landfills. Major problems are anticipated only in areas where bedrock crops out. Excellent sites exist in the many small gullies and in those areas where limestone quarrying necessitates stripping the land.

Impoundments. Few limitations are placed on lake development. The problem most often encountered involves exposed bedrock, where leakage may occur.

Construction. Problems anticipated include freeze-thaw breakup of roads, slope failure, and drainage impedance by impermeable shale.

Unit Three - Alluvial Soil (Al)

This unit is located in the valleys of the major streams. Thickness of the alluvium in the Chariton River valley is 40 to 60 feet. This alluvium consists of gravel, sand, silt and clay.

Sewage Lagoons. Several problems should be anticipated. Flooding is frequent, and levees must be constructed to protect the lagoon. Material used to build the levees should not come from the lagoon site. Deepening of the lagoon to obtain construction materials could expose permeable subsoils and cause groundwater pollution at least during times of high water.

Septic Tanks. Septic tanks should be used only on farms or for widely scattered homes.

Sewage Treatment Plants. Few problems are anticipated. Low water during summer months (or during droughts) may cause inadequate dilution.

Sanitary Landfills. Land in the alluvial valleys should not be utilized for landfill sites. Flooding is frequent, and soils are highly permeable. The major reason for discouraging development of sanitary landfills is that these alluvial valleys are excellent sources of groundwater and therefore should not be tampered with. Excellent sites for landfills can be found nearby in the plains areas.

Impoundments. Few problems will be encountered with small impoundments. Lakes and large ponds may have leakage problems and are more susceptible to damage by flooding.

Construction. Problems encountered include variable permeability and strength, flooding, and a high water table.

* * * For additional geologic information concerning Adair County see these selected references: 3, 6, 7, 8, 10, 11, 13, 14, 15, 16, 17, 18, 20, 21.

MARION COUNTY, MARK TWAIN REGION

Summary

Marion County has a varied topography with flat lowlands, plains and rugged hills. Relief in general seldom exceeds 75 feet, but along the Mississippi River bluffs relief may exceed 250 feet. The floodplain of the principal stream, the Mississippi River, is very wide and south of Hannibal is frequently flooded. The floodplains of the county's smaller streams are narrow and seldom exceed 1/3 mile in width.

Bedrock formations consist primarily of limestone, shale, and dolomite. Glacial till and loess deposits cover bedrock. Soil cover has developed from weathered bedrock, till, and loess, and its thickness and composition are variable. Soil thicknesses vary from 0 to 100 feet; soils consist of silty-clay, clayey-silt, and stony clay. Alluvial soil is generally a sandy to gravelly silt or clay.

Marion County is not considered to be in danger of earthquake activity.

Mineral resources currently being produced include stone, sand and gravel. Limestone is quarried at several locations for use in construction aggregate, cement, and aglime. Sand and gravel are dredged mainly from Mississippi River deposits, with minor amounts being taken from the Salt River.

Water resources are plentiful, and water needs for any anticipated growth in the area can be met easily. Both surface water (from the Mississippi River) and groundwater are currently utilized. Groundwater production is limited to shallow wells in bedrock formations (because of mineralization) and alluvial wells. Chemical quality of the water necessitates that it be treated.

Successful land use (construction and waste-disposal) requires careful geologic investigation. On-site inspection is necessary to determine the suitability of each proposed site for the project being planned. Waste-disposal sites can be located with minimal difficulty, but in some cases require remedial measures to insure success and prevent groundwater pollution.

Problems similar to those encountered with regard to land and resources development in Marion County will be encountered in adjacent areas of the surrounding four counties.

This report is intended to serve as a regional appraisal of the geologic features, resources and problems of Marion County. It is not intended to furnish all the information needed for geologically oriented development and cannot be a substitute for actual on-site investigation of proposed development sites.

Landforms and Relief

The topography of Marion County is diverse. In the southwestern portion of the county there are smooth plains. The relief in this area generally ranges from 50 to 75 feet. East of this area is a moderately dissected plain. Hills are more prominent and the relief is usually greater, varying from 50 to 200 feet. Along the Mississippi River are found flat lowlands. Bluffs along the Mississippi River often have relief exceeding 250 feet.

Rock and Soil Formations

The bedrock formations of Marion County consist primarily of cherty limestone, shale, and dolomite units. Glacial till and loess (wind-blown silt) are deposited over these bedrock units. The till deposits are usually thick (30 to 40 feet) and consist of boulders, gravel, sands, clays, and silt. The loess varies in thickness from 2 to 20 feet. Soils include stony, silty-clays; clayey-silt; and stony clay. Thicknesses vary, but in general range from 0 to 100 feet, depending on location and parent material. In the alluvial valleys (of the Mississippi, Salt, and North Rivers) soil consists of an admixture of river-deposited materials (gravel, sand, silt, and clay). Thicknesses vary, but are greatest along the Mississippi River.

Earthquake Potential

The bedrock units in Marion County dip away from the axis of the Lincoln fold, a major northwest-southeast-trending structural feature. Several small, inactive faults are associated with this fold. Marion County is not considered to be in danger of earthquakes.

Scenic Natural Resources

Many caves and springs are found in Marion County. Sixteen caves have been reported. Two of these caves, Mark Twain and Cameron, have been commercialized and are open to the public.

Mineral Resources

The mineral resources of the Hannibal area are limestone, sand and gravel, and shale. Lime and cement are products manufactured from high calcium limestones.

Stone. Limestone is the major mineral resource of the area. Reserves of high-calcium stone are present north, west, and south of Hannibal. This stone is used for the manufacture of lime at several plants in Illinois. South of Hannibal, the same unit is used for the manufacture of cement. Considerable stone is also used for construction aggregates and aglime.

Sand and Gravel. Sand and gravel production is limited principally to sand dredged from the Mississippi River, with minor production from the Salt River. Whether any deposits of gravel similar to those at LaGrange are present is not known. Unlimited resources of sand are present, but only minor amounts of gravel.

Shale. Resources of shale suitable for the manufacture of structural clay products are present in several areas. The economic potential of these resources is not known.

Oil and Gas. There is a possiblity of minor oil and gas production from along the Lincoln fold in western Marion County.

Water Resources

Hannibal, the principal city, obtains its water supply from the Mississippi River. For a time, Palmyra obtained water from North River. The low-flow characteristics of this stream were such that during drought periods an ample volume of water was not assured. Palmyra then developed alluvial wells in bottom land of North River, and this was utilized until recently. Palmyra now obtains its water from alluvial wells along the North River near the lowlands of the Mississippi River valley.

Monroe City, located mostly in Monroe County, but in part in Marion County, obtains water from impoundments.

Surface Water. The Mississippi River, with its very large flow, is an assured water source which will meet all anticipated growth needs. Minimum water stages are maintained for navigational purposes by a series of locks. This stability lessens the problems in designing and operating the inflow mechanisms of water systems.

A large potential exists for development of water supplies by the construction of impoundments. Water from such impoundments would be of better quality than that from the Mississippi River. It is unlikely, even with tremendous population increase, that either Palmyra or Hannibal would change their water source however. Except for recreational needs and the needs of farming operation, it is unlikely that the construction of impoundments will be necessary.

Groundwater. The groundwater obtained from the rock formations is saline. This salinity precludes the utilization of deep bedrock wells for municipalities, water districts, industry, irrigation, and other uses. In the deeper formations, the salinities exceed 10,000 parts per million total dissolved solids. Rural water needs for residents and livestock can often be supplied by shallow bedrock wells. These wells seldom exceed 300 feet in depth. Because of the increasing salinity with depth, wells are generally terminated at a horizon which is productive of water sufficiently low in salinity that it can be used in homes or by livestock. These shallow wells generally have a yield of less than ten gallons per minute.

Covering the uplands is glacial drift. Sands and gravels in the basal glacial drift have a limited capacity to yield groundwater. These thin sands and gravels have not been utilized for water supplies.

The valleys of North Fabius, South Fabius, and North Rivers have alluvial fill which averages less than 50 feet in thickness. Yields exceeding 200 gallons per minute have been obtained from this alluvial material. The quality of this water has been excellent, with iron sufficiently low that its removal has not been required.

As mentioned previously, Palmyra turned to the more prolific water source of the alluvial fill of the Mississippi valley.

Extending northward from Hannibal and beyond the Lewis County line, the Mississippi River has a floodplain which in places exceeds three miles in width. The alluvial fill of the valley approaches 120 feet thick at maximum. Yields to individual wells sometimes exceed 1,000 gallons per minute. Currently, groundwater withdrawal from this aquifer is insignificant in terms of its total capability. Current utilization is by Northeast Missouri Power Cooperative and two other industries immediately adjacent to this power-generating facility. Except for high iron and manganese content this water is of sufficiently good quality for many uses; iron and manganese must be removed. Recharge of this aquifer system occurs quickly from the Mississippi River.

With the enormous volume of water obtainable directly from the Mississippi River and from the alluvial fill of the Mississippi River valley, Marion County has an abundance of water. Water resources will never be a limiting factor for the future growth of this area.

Land Use

In order to insure proper land use, it is necessary that several things be known. These include strength of bedrock and soil present in the area and their relationship to the area's water resources. Six engineering-geology units are present in Marion County.

Unit One - Thick Glacial Soil (G1)

This unit encompasses most of northwestern Marion County. The soil is a silty-clay mixed with stones. The thickness, which is about 30 feet in the south, increases in the north.

Sewage Lagoons. Few problems are anticipated in those areas where the soil is very clayey. Problems with leakage will be encountered locally where the soil is silty, but with the use of sealants such as bentonite the site can be used successfully. The effluent from these lagoons should not be allowed to seep into silt or sand-rich zones because of rapid percolation into the subsurface.

Septic Tanks. The use of septic tanks in this unit should be limited because of unfavorable silty clays.

clay will cause the sewage effluent to resurface, and this will result in surface pollution. Septic tanks can be used in areas of low population density.

Sewage Treatment Plants. Streams with persistent flow (needed for proper dilution) include the South Fabius and North Rivers and major tributaries. However, many minor tributaries have extremely low flow during the summer months.

Sanitary Landfills. Excellent sites for sanitary landfills can be found with little difficulty. The rugged hills present in central Marion County are generally covered with thick silt deposits. Because the gullies between hills are small, problems encountered with surface runoff are significantly reduced. Although the silts are permeable, there are often thin clay seams that will act as barriers to seeping leachates. Borrow material is plentiful. Where soils are thin, the amount of soil available for cover material and padding is often inadequate, and the site will need improvements before it can be used. Clay padding can be used to increase the impermeability of the landfill floor to prevent leachate escape. Suitability of landfill sites will generally depend on the amount of clay present in the soil.

Impoundments. Farm ponds and lakes usually can be constructed successfully. Good water retention can be expected in gully sites because of thicker silts and clay seams. However, valleys eroded into limestone may be poor locations for lakes due to permeable bedrock.

Construction. Problems encountered include slope failures on hillsides or road cuts and freeze-thaw breakup of roads. In some areas, problems arise from swelling subsoil clay and poor drainage.

Unit Two - Thin Glacial Soil Over Cyclic Bedrock (Gl-Cy)

This unit is in southwestern Marion County. The thin (less than 40 feet) glacial soil is a stony, silty clay. Exposed bedrock is usually limestone or shale.

Sewage Lagoons. Much of this area is suitable for lagoons. However, lagoons which require excavation into hillside or bedrock should be avoided. Slope failure and/or leakage of effluent to bedrock often will occur.

Septic Tanks. Septic tanks should be used only where three or more acres per tank are available. Poor soil conditions (high permeability and insufficient thickness) are not conducive to good filtration of effluent. In areas where the soil is very thin, surface or groundwater pollution will occur.

Sewage Treatment Plants. There are no major problems anticipated. There is little loss of stream flow to bedrock. The major stream, the South Fork, and several smaller streams have sustained flow through most of the year. However, during periods of low rainfall there may be periods of inadequate dilution, expecially on smaller tributaries of the larger streams.

Sanitary Landfills. Major problems are anticipated in areas where bedrock crops out. Excellent sites exist in the many small gullies where soil is thick.

Impoundments. Few limitations are placed on lake development, except where limestone bedrock is extensive. The problem most often encountered involves the exposed bedrock, where solution-enlarged openings exist.

Construction. Anticipated problems include freeze-thaw breakup of roads, slope failure and drainage impedance by impermeable shale.

Unit Three - Thin Glacial Soil Over Carbonate Bedrock (Gl-Ca)

This unit is located in northern and western Marion County. The bedrock is massive limestone. Soil cover is generally a clayey or stony-clay soil of variable thickness. Karst features such as caves, sinkholes, pinnacles, and solution channels are common.

Sewage Lagoons. Lagoon sites can be located without too much difficulty except in areas of sinkholes. The thick (40 feet) glacial soils are suitable for use in construction of levees for the lagoons. In areas where karst is a problem, lagoons should not be built. Serious leakage could occur with pollution of the groundwater supply.

Septic Tanks. The use of septic tanks should be restricted to rural and farm areas. The soils in this unit are generally not very permeable, and a larger-than-usual waste field will be necessary to insure proper filtration of the effluent.

In areas where karst prevails, septic tanks should drain away from sinkholes to avoid groundwater pollution.

Sewage Treatment Plants. Sites suitable for treatment plants may be difficult to locate. Discharge should be only into those streams with sustained flow. Streams that flow only part of the year, or losing streams, are poorly suited because of the problems associated with karst.

Sanitary Landfills. Satisfactory sites can be located without extreme difficulty. The thick loessial soil provides adequate cover material for the landfill. In areas of karst, landfills should be located away from any sinkholes, or leakage may occur into the groundwater system.

Impoundments. Farm ponds and small lakes can be constructed with little difficulty in those areas unaffected by karst.

Construction. Minimal problems are anticipated in those areas unaffected by karst.

Unit Four - Carbonate Bedrock With Some Shale (Ca-Sh)

This unit is in central and eastern Marion County. Bedrock is composed primarily of limestone and shale, but there are local areas of sandstone. Soil is a clayey-silt. Thickness of the soil is less than 30 feet.

Sewage Lagoons. Sites satisfactory for sewage lagoons can be located with relative ease in this area, except where the terrain is more rugged and where soil is thin. Most problems can be overcome by choosing a proper site. Remedial measures may be advisable. For example, only a portion of a lagoon site may be suitable, but with the addition of clay or bentonite, seepage loss could be prevented. Because conditions at each proposed lagoon site will vary, an investigation should be made to determine the capabilities of each site.

Septic Tanks. Due to the varied nature of the bedrock (carbonates and shales), a detailed study is necessary for each proposed site. The success of a given septic tank will depend upon the characteristics and depth of the soils present and the density of septic-tank development.

Areas that have shallow soils along the Mississippi River in the southeastern portion of the county are poorly suited for septic tanks, except perhaps for rural areas such as farms or large estates. The remaining part of unit one has soil cover sufficient to permit septic tanks to be used in lightly urbanized areas where lot sizes exceed three acres.

Sewage Treatment Plants. Sewage-treatment plants can be located without much difficulty relative to geologic conditions of the receiving stream. All treatment plants should be located so that discharged effluent will enter gaining streams, which are common in this unit.

Sanitary Landfills. Sites that are acceptable for landfills are for the most part limited to areas of thick soil cover. Soils in portions of the county are not well-suited for sanitary landfills. However, possibilities exist for satisfactory landfill sites in other parts of this area, but extreme caution should be used when selecting a site.

Impoundments. Most areas are suitable for lake development. Areas where carbonates and sandstones crop out may have some seepage problems, but padding with clays may help prevent leakage. In a few extreme cases, more costly treatment procedures may be required.

Construction. No serious problems are anticipated in finding sites where small buildings such as houses can be built. Careful examination should be made of the bedrock and soil, however, when buildings larger than homes are to be constructed and for any buildings to be erected on a steep slope.

Unit Five - Karst (Ca-K)

This unit is in central southeastern Marion County. Bedrock consists of very permeable limestone. Karst features such as caves and sinkholes are well-developed throughout the area and present a considerable challenge to successful land development. Soil depths vary from 0 to 40 feet, and the composition is generally a very cherty clay.

Sewage Lagoons. Sewage lagoons should not be used in this area. The high permeability of both soil and rock will prevent the lagoon from retaining effluent. Contamination of the area's groundwater resources is likely.

Septic Tanks. Many problems will be encountered in locating sites suitable for septic tanks. Only those areas where thick, clay-rich soils are present should be considered acceptable. Septic-tank use, in most cases, should be restricted to rural or farm settings where three acres or more are available as a filtration field for each tank.

Sewage Treatment Plants. Because of the highly permeable nature of the soil and bedrock, discharge should be limited to stream with continuous flow. A few streams lose surface flow to groundwater supplies.

Sanitary Landfills. Sites suitable for sanitary landfills will be difficult to locate. Gullies and small, tight valleys with deeper soils are possible sites of limited size. Sinkholes should not be used as sanitary landfills because of the direct connection they have with the groundwater system. Whatever the setting, subsurface exploration will be necessary before final decisions can be made.

Impoundments. Suitable sites will be difficult to locate. Small farm ponds may be constructed, but remedial measures will probably be necessary. Usually, bentonite and/or impermeable clays can be used successfully to control leakage. There is some danger of catastrophic collapse with larger impoundments because of the increased loss of strength due to wetting of subsoil. Careful investigation will be necessary to determine the strength of bedrock at the various proposed sites.

Construction. Problems encountered include subsurface drainage, variable soil depth to bedrock, and variable soil strength dependent on moisture.

Unit Six - Alluvial Soils (Al-Tu and Al)

Unit six is located in eastern Marion County along the Mississippi River and in the valleys of the county's major streams. The area is an alluvium-filled valley. Soil is composed of weathered loess, sand, silt, clay and gravel. The water level in this unit is shallow and is perhaps the most important factor to be considered in land development. Surface flooding along the Mississippi River and streams unportected by levees is also a very important factor in land use development.

Sewage Lagoons. Lagoons can be built successfully if proper precautions are taken. Great care should be exercised in keeping the lagoon floor well above the water table and seeing that an adequate thickness of clay padding is left between the lagoon floor and the water table. A lagoon should also be protected from damage by floodwaters by building high banks around it. If borrow material is required for constructing these high banks, it should be obtained from outside the perimeter of the lagoon, not by deepening the lagoon interior.

Septic Tanks. The use of septic tanks should be restricted. In sandy areas, use should be limited to rural settings. In clayey areas, they can be used in lightly urbanized settings with less danger of polluting the groundwater system.

Sewage Treatment Plants. Few problems will be realized from treated effluent if the discharge is limited to streams with sustained flow.

Sanitary Landfills. Because of a high water table and the possibility of flooding, few sites exist for sanitary landfills. Favorable sites are those where there is a thick, clay-rich soil which can prevent leachates from leaking into the groundwater. These sites require careful selection and must be evaluated to determine the hydrologic characteristics of the alluvial groundwater system.

Impoundments. Only small ponds or lagoon-type impoundments can be considered due to the high groundwater level. These could be built in areas of impermeable clay soils near small hills or ridges.

Construction. Problems will be encountered. Buildings with basements will probably be flooded at times unless groundwater can be diverted. Settlement problems may occur where excessive or vibratory loads exist or where more than one soil type underlies the foundation.

* * * For additional geologic information concerning Marion County see these selected references: 3, 5, 6, 7, 8, 13, 14, 15, 16, 17, 18, 20, 21.

CASS, CLAY, JACKSON, PLATTE AND RAY COUNTIES -

MID-AMERICA REGIONAL COUNCIL

BUCHANAN COUNTY - MO-KAN BI-STATE REGION

JOHNSON AND LAFAYETTE COUNTIES - SHOW-ME REGION

(Limited to the General Boundaries of Sensitive Area #23)

Summary

The topography of this eight-county (Buchanan, Cass, Clay, Jackson, Johnson, Lafayette, Platte and Ray Counties) area is relatively unvaried. Moderately dissected plains are north of the Missouri River and rolling plains are south of the river. The Missouri River is the major stream in the region and it has a wide floodplain. Flooding is common in the spring and summer.

Bedrock formations consist of limestone, shale, sandstone and some coal. There is a thick till over this bedrock material (north of the Missouri River only). Covering the till deposits in the north and bedrock in the south is a deposit of wind-blown silt (loess) which is thicker in the north than in the south. Soils developed in the area include silty-clay and sandy-clay types.

Earthquake activity is not anticipated within this region and should not be a problem.

Mineral resources currently produced include shale, sand, gravel, stone, oil and gas. Coal is not being mined but several billion tons are known to be present as deep reserves. Limestone reserves are adequate. Sand and gravel can be obtained from alluvial deposits; resources of the alluvial deposits are plentiful. Shale is quarried for manufacturing lightweight aggregate and cement and reserves are adequate for many years. Oil and gas are produced on a small scale, and while the area may have additional unknown reserves it is unlikely that large quantities are present.

Water resources are plentiful with the Missouri River being the primary source of surface water in the region. Quality of this water varies from poor to fair and treatment is required to make the water safe to drink. Groundwater is obtained primarily from alluvial deposits and very little is obtained from bedrock sources. High yielding wells can be constructed in alluvial deposits and yields may exceed 500 gallons per minute. This water requires treatment.

Several engineering-geology units are in this area and future development within each unit will depend on its bedrock and soil characteristics. Sites suitable for solid- and liquid-waste disposal can be found throughout the area, but may be somewhat difficult to locate in Lafayette and Johnson Counties. Careful on-site investigation by a geologist is recommended in order to select the best site for each project and to avoid subsequent water pollution.

Similar land conditions and problems will be encountered in the immediately surrounding counties.

This report is intended as a broad regional appraisal of the geologic features and geologically oriented problems that might be encountered in future land-use development in this area. It is not intended to take the place of careful on-site investigation at future development sites, but is intended to supplement actual findings.

Landforms and Relief

This eight-county area has fairly uniform topography. In the north, where the plains have been moderately dissected by streams, relief is commonly 100 to 200 feet. South of the Missouri River the area is dominated by low, rolling hills and relief is 60 to 150 feet. Slopes in both of these areas are commonly gentle, but may be as great as 25 percent. The two plains areas are separated by a flat lowland area which serves as the floodplain of the Missouri River. Width of the floodplain varies from 2 to 6 miles. This area is often flooded during the spring and late summer.

Rock and Soil Formations

Bedrock formations consist of alternating (or cyclical) beds of limestone and shale. These units are generally thin, and thicknesses vary from 6 inches to 20 feet. Shale beds vary in thickness from 1 to 15 feet. Some sandstone crops out in central Lafayette County. The area north of central Jackson and Lafayette Counties has been glaciated, and thick till deposits are present. Over these till deposits is a deposit of loess. Glaciation did not occur south of this area and only a deposit of loess is present. The thickness of this loess varies from 2 feet in the south to more than 20 feet in the north. Soils have been developed on the limestone, shale, sandstone, till and loess, and reflect the character of the parent material. Soils are predominantly silty-clay and sandy-clay types.

Earthquake Potential

For the most part, strata in this eight-county area are flat-lying; however, locally there are areas where beds have been folded. There are several anomalous structures where strata have folded and then faulted. Here the dips are steep and in two places in Cass County these structures have downdropped centers. Several dome structures are present and serve as gas traps. There are two major and several minor anticlines. These small anticlines serve as gas traps. Earthquake activity is not considered to be a problem.

Scenic Natural Resources

There are some caves and springs of geologic interest in this area. Only seven caves are reported with one being in Clay County, four in Jackson County and two in Johnson County. No large springs are present, although many small springs can be found.

Mineral Resources

The mineral resources of the Kansas City - St. Joseph region include shale, sand and gravel, stone, coal, and oil and gas. It is anticipated that mineral production will increase along with future growth of the area's population.

Shale. Currently two companies are quarrying shale for use in the manufacture of brick and lightweight aggregate. Lightweight aggregate is manufactured by the Carter-Waters Corporation and the Missouri Portland Cement Company produces portland and masonry cement. Shale reserves are considered to be practically unlimited.

Sand and Gravel. There are several sand and gravel producers in this area. Sand and gravel are produced from Missouri River alluvium and are used for building and paving sand. Reserves of sand from the Missouri River are almost unlimited.

Stone. Limestone, quarried by 30 companies in the Kansas City - St. Joseph area, is used for dimension stone, aglime, construction aggregate, rip-rap and cement manufacturing. Reserves of stone in the area appear to be adequate for many years. Deeper limestone reserves will require underground mining in order to be utilized. A deep-shaft limestone mine project is now underway by Centropolis Crusher, Inc. in Kansas City.

Coal. Coal is not being mined now although approximately 3.75 billion tons of coal are present as deep reserves. Development of these reserves will depend largely on growing needs for energy and rising costs.

Oil and Gas. Oil and gas have been produced in the Kansas City - St. Joseph area since the late 1860's. At present only oil is being commercially produced in Cass and Jackson Counties. While there is no commercial production of gas, there are many individual privately-owned wells that supply enough gas to heat single-family dwellings. Oil production is presently approaching the limits of profitable recovery. Chances for discovery of additional oil reserves are geologically good but are hampered by urbanization and population growth. Because most of the wells in the area produce less than 10 barrels of oil per day, land is now worth more as real estate than oil property.

Water Resources

Usable water resources in the Kansas City - St. Joseph area are limited to two sources, surface water and alluvial groundwater. Bedrock sources will be discussed only briefly.

Surface Water. Kansas City is fortunate in that the Missouri River offers an almost unlimited supply of water. The quality of this water is only fair and, at times, is poor. Treatment of this water to make it potable is expensive, but because of the consistent quantity involved, it is a distinct asset. Because of the nature of the underlying bedrock material, surface impoundments for water supply are feasible in this area.

Groundwater. The unconsolidated alluvial deposits of the Missouri River valley are capable of yielding large quantities of water to wells. Yields in excess of 500 gallons per minute are available from large-diameter, gravel-packed wells completed in alluvial materials.

These deposits yield water which is often high in dissolved iron, and treatment to remove this iron is needed. Because these deposits have good communication with both the river and with other surface-water sources, they are extremely susceptible to contamination, and the water should be treated.

The bedrock in this area comprises shale, thin limestone and siltstone beds. The permeability of this material is very low and yields from shallow wells (50-200 feet) are very poor (1-3 gpm). The quality of water from these deposits is often quite poor also, with high sulfates, chlorides, nitrates and total dissolved solids. Wells drilled deeper than 200 feet in this area almost always encounter water which is too highly mineralized for any use.

Land Use

In order to establish criteria for proper land use, it is necessary to have an understanding of the characteristics and engineering properties of bedrock, soil and water resources of the proposed development areas. This eight-county area is divided into five engineering-geology units as shown on the Engineering Geology map included in the Stout and Hoffman report.

Unit One - Thin Glacial Soil Over Cyclic Bedrock (Gl-Cy)

This unit is in eastern Buchanan, eastern Platte and northern Clay Counties. Bedrock is variable, consisting of limestone and shale and soil is a silty clay mixed with stones. Soil depths vary from 0 to 40 feet.

Sewage Lagoons. Sites suitable for lagoons can be easily located. In most cases adequate quantities of borrow material, till, and residual clay are available for lagoon construction. Lagoons should not be built in those areas where bedrock crops out or is near the surface or where the topography is rugged because percolation of lagoon waters into the bedrock will cause pollution problems. Where thick silty soils are present, a sealant may be necessary.

Septic Tanks. Suitable sites are difficult to locate in areas where thick silts are present because of high permeability, or in areas where very clayey soils are present because of impermeability. Septic tanks should be used in areas where the soils have moderate permeability and are at least 20 feet thick.

Sewage Treatment Plants. No special problems are anticipated in choosing a suitable site.

Sanitary Landfills. Suitable sites are difficult to locate. The till and silt layers provide excellent borrow material for a landfill, but in areas where bedrock is close to the surface, there may be some problems in locating enough borrow for the landfill.

Impoundments. Small farm ponds can be located where clay soils have been developed or where clayey shales are exposed. These ponds are likely to fail where silty soils or fissile shales are present. Larger impoundments can be built without many problems in areas underlain by clay shales or limestone. There may be some leakage where limestone bedrock crops out, but this can usually be corrected by grouting the bedrock.

Construction. Problems that are frequently encountered include freeze-thaw breakup of roads, drainage impedance by impermeable bedrock and slope failure in road cuts.

Unit Two - Carbonate and Cyclic Bedrock (Ca-Cy)

This unit is in western and southern Jackson and western Cass Counties. Bedrock consists of alternating shale and limestone beds. The limestone is generally permeable because it contains joints and fractures and soils include both silty clays and silty loams. Thickness of the soil cover is usually less than 40 feet. These soils have low permeability.

Sewage Lagoons. Many problems are encountered in selecting a site suitable for development. The presence of massive limestones and rugged topography is not generally favorable to water retention. Suitable sites are often available in floodplains of smaller streams. Often there is not enough borrow material for construction so additional material will have to be transported to the site. Suitable material is frequently available nearby, usually at higher elevations. There is little danger from flooding.

Septic Tanks. The use of septic tanks in this unit is not recommended. Thin soil cover and permeable limestone bedrock facilitate the rapid movement of untreated sewage effluent. Groundwater pollution is not considered a major problem although surface pollution can be expected. Septic tanks should be used only where soil cover is greater than 20 feet thick and in a rural setting.

Sewage Treatment Plants. No problems are anticipated in selecting a favorable sewage-effluent discharge point. However, developers should have the proposed sites investigated by an engineering geologist and approved by the Missouri Division of Health.

Sanitary Landfills. Thin soil cover and carbonate bedrock are not conducive to landfill development. Proposed sites should be thoroughly investigated to insure that adequate soil cover material and padding will be available.

Impoundments. Those problems encountered in selecting a sewage lagoon site will be encountered here also. Small farm ponds may be possible in areas where clayey soils are thickest but some leakage can be expected.

Construction. Problems most often encountered include freeze-thaw breakup of roads and slope failure in road cuts.

Unit Three - Cyclic Sedimentary Bedrock (Cy)

This unit is in Lafayette and Johnson Counties. Bedrock consists of alternating shale, limestone, sandstone and coal beds and soil is a silty clay. Both the rock and the soil have low permeability.

Sewage Lagoons. Sites suitable for development as sewage lagoons can be located with little difficulty. Sufficient quantities of borrow material for construction of the lagoon can easily be obtained on site. This silty clay soil is ideal for water-retention projects.

Septic Tanks. Septic tanks should not be used within this unit because soils are not permeable enough to allow the effluent to permeate downward and be filtered. Surface pollution is the greatest hazard. An investigation is necessary in each case to determine if a tank can be used successfully.

Sewage Treatment Plants. There are no special problems anticipated. On-site investigation is necessary to determine a suitable discharge point in order to avoid any possible water pollution.

Impoundments. There should be no difficulty in constructing lakes or ponds, except where bedrock is encountered. There may be minor loss of water to bedrock.

Construction. Problems encountered in construction projects include ponding of water on the surface where drains are provided, and slope failures in road cuts.

Unit Four - Sandstone Bedrock

This unit is in a narrow band in central Lafayette and Johnson Counties. Bedrock consists of a massive sandstone with high permeability.

Soil cover is thin (usually less than 10 feet) and consists of a silty to sandy clay.

Sewage Lagoons. The use of sewage lagoons is discouraged. Soil cover is too thin and permeable to afford adequate water retention. Pollution of groundwater is likely.

Septic Tanks. It is not advisable to use septic tanks within this region for the reasons given under sewage lagoons. They may be utilized in isolated cases, however, such as where soils are thick and not too permeable. Their use should be restricted to farms in any event.

Sewage Treatment Plants. These can be utilized only in those areas where discharge can be regulated so that effluent will not enter the sandstone bedrock.

Sanitary Landfills. Inadequate amounts of borrow material for cover material and construction will, in most cases, restrict the use of sanitary landfills. In general the soil cover is too permeable and is not thick enough to retain leachates, so pollution can occur.

Impoundments. Few places within this unit can be utilized for impoundments although, in come cases, leakage can be controlled by grouting or by using bentonite.

Construction. No serious problems are anticipated.

Treatment Plants. No serious problems are encountered in disposal of treated effluent. Discharge should be directly into the river so that the treated effluent can be properly diluted.

Sanitary Landfills. The use of sanitary landfills in a floodplain setting is not recommended. The high, fluctuating water table will create problems in controling leachates and in the strength of the landfill. Flooding can be a problem.

Impoundments. Much of the sand and gravel soil of the floodplain is not conducive to retaining water; however, where these soils have mixed with the clay soils from nearby slopes, lakes and farm ponds can be built.

Construction. Problems encountered include flooding, seepage into basements, and variable soil strengths.

Unit Five - Undifferentiated Thick Alluvial Soil (Al)

This unit is adjacent to the Missouri River. Soil consists of alluvial material which is an admixture of gravel, sand, silt and clay. Thickness varies and is usually greater than 40 feet but it may be thin locally. Permeability and strength vary.

Sewage Lagoons. The wide Missouri River floodplain offers many good sites for sewage lagoons. Because of the high groundwater table lagoons should be built on the surface of the floodplain. Materials needed for completing the lagoon floor and walls can be obtained nearby. Problems may arise because of the fluctuating water table and possible flooding. Effluent should be discharged in an area where it will seep slowly enough so that it will be properly filtered.

Septic Tanks. The use of septic tanks is discouraged except in isolated cases.

Sewage Treatment Plants. Sites suitable for discharge points can be located with minimal difficulty. These sites must be located so that effluent will not enter permeable bedrock or alluvium.

Sanitary Landfills. Satisfactory sites can be located on nearby slopes away from the river. Flooding may be a problem.

Impoundments. Small lakes and ponds can be constructed with minimal difficulty.

Construction. Because of flooding and the high groundwater table construction of buildings should be discouraged on the floodplain.

* * * For additional geologic information concerning the Kansas City - St. Joseph area see these selected references: 3, 6, 7, 8, 10, 11, 13, 14, 15, 16, 17, 18, 20, 21.

PETTIS COUNTY, SHOW-ME REGION

Summary

Pettis County lies completely within a plains region. Dissected plains dominate the topography in the east and relief rarely exceeds 200 feet. In the west, rolling plains prevail, and relief is generally no more than 100 feet.

The bedrock of Pettis County consists of limestone, dolomite, shale, sandstone, and some coal. Residual soil and loess overlie the bedrock. Some glacial till is present in the northeastern corner of Pettis County. The soils in Pettis County are generally red, silty-clay, or red, sandy-clay types but, locally, can be stony. Thicknesses range from a few feet in the south to 40 feet in the north. Alluvial deposits found in stream valleys are generally thin but can be thicker locally.

There is no anticipated danger of earthquakes in Pettis County.

The mineral production of the county is limited to stone. Limestone is quarried for crushed stone. Barite and coal were produced in the past.

Water supplies are obtained primarily from groundwater sources. Domestic wells produce from 15 to 50 gallons per minute, and public water-supply wells have yields ranging between 90 and 1,400 gallons per minute. Any increased need for water will most likely require additional wells. Surface water is an unreliable source because of the low-flow characteristics of the area's streams.

Proper land use within the county will require on-site geologic investigations at each proposed waste-disposal site. Problems will be encountered with waste disposal in areas where thin soil is present. Much of the soil in the county is unsuitable for the use of septic tanks except in rural settings where the soil is thick. Waste disposal by using a centralized waste-treatment system is the most favorable method. Sanitary landfills can be constructed with few difficulties in western Pettis County. In the eastern portion of the county it may be necessary to use more extreme remedial measures to make the proposed site suitable for a sanitary landfill.

Similar problems with land use are encountered in the adjacent areas of the surrounding seven counties.

This report is intended to serve as a regional appraisal of the geologic features, resources, and problems of Pettis County. It is not intended to furnish all the geologic information needed for development and can not serve as a substitute for the actual on-site investigation needed at each proposed development site.

Landforms and Relief

Pettis County is relatively flat. In the eastern third of the County, a highly dissected plateau dominates. Relief in this area varies from 100 to 200 feet, with the areas of greatest relief lying along Muddy Creek. Slopes vary from moderate to very steep (e.g., Muddy Creek bluffs). Floodplains in the larger valleys vary from 1/3 to 2/3 mile wide.

The western two-thirds of Pettis County is dominated by gently rolling plains. Gentle slopes prevail and relief varies from 50 to 100 feet. The major streams in this area are Muddy Creek and Flat Creek. Floodplains in these major valleys are generally narrow and seldom exceed 1/3 mile wide.

Rock and Soil Formations

The bedrock formations in Pettis County consist of limestone, dolomite, and shale. In the extreme northeastern corner of the county, glacial till (mixed gravel and sand) is present over bedrock. A veneer of wind-blown silt (loess) is deposited over the till and bedrock. These loess deposits are generally thin, varying from 2 feet in the south to 10 feet in the north.

Several soils have developed from these bedrock, till, and loess materials and are of varying thickness and composition. In the west and northeast, soil thicknesses range from 15 to 20 feet, with the soil type being a cherty clay. In the east-central portion of the county the soils are thin, varying from 5 to 10 feet, and they are a silty-clay to sandy-clay type. In the southeastern corner of the county the soils are thickest, being about 30 to 40 feet, and are a red, cherty-clay to red, cherty, sandy clay.

The stream valleys have deposits of alluvial clay, silt, sand and gravel. Thickness of these alluvial deposits is often slight (10 feet), but may be greater locally.

Earthquake Potential

The bedrock formations of Pettis County are essentially flat-lying, with a very gentle, imperceptible dip toward the northwest. Pettis County is not considered to be in danger of earthquake activity.

Scenic Natural Resources

Only two caves have been reported in Pettis County. Both are privately owned and are not open to the public. There are no large springs in the county.

Mineral Resources

Mineral production in Pettis County has been limited mostly to stone.

Stone. Reserves of limestone for the production of crushed stone constitute the most important mineral resource in the county. Two quarries are operated near Sedalia.

Coal and Barite. Very small, unimportant reserves of coal and barite of marginal economic value are present also. Minor amounts have been produced in the past.

Water Resources

The water resources of Pettis County are primarily restricted to groundwater. Large surface-water supplies could probably not be developed due to the low-flow characteristics of the streams draining the county.

The geology of this area is fairly complex, and because of this complexity, the hydrology of the area is extremely variable, particularly in the shallower aquifers. The southeastern corner of the county is directly underlain by dolomite and sandstone. The remainder of the county is directly underlain by limestone, shale, dolomite, coal and sandstone which are younger than the deposits described above. The older deposits are present at depth underlying the younger limestone, shale and sandstone deposits. This relationship yields a two-layer type of hydrology over a large area of the county.

The upper part of the younger limestone and shale deposits consists of rather coarse, crystalline limestone which weathers at a relatively fast rate. This unit has high permeability and develops a rather "open" character which allows water to move freely, both vertically and horizontally. Because of this "openness", water contained in this unit is under very little artesian pressure and hence will not rise up in a well above the point at which it was encountered in drilling. Below this unit are more than 100 feet of "tight" limestone and shale through which very little water moves. At the base of this "tight" zone, a fairly pure quartz sandstone locally occurs and is water-bearing. Where this sandstone is not present, the "tight" limestone sequence rests directly on the older, dolomite sequence mentioned above.

Domestic wells bottoming in the younger limestone generally do not yield sufficient quantities of water for modern household needs. Most domestic wells drilled in the northern and western part of the county completely penetrate the younger rocks and extend into the older, better-yielding dolomites. These deeper wells have yields ranging between 15 and 50 gallons per minute. The depths of these deeper wells range between 350 and 500 feet, with casing depths ranging from 70 to 350 feet.

Domestic wells drilled in that part of the county where the older dolomites are exposed at the surface range in depth from 250 to 450 feet and have yields of from 15 to 30 gallons per minute. Casing depths range from 80 to 150 feet.

Public water-supply wells penetrate the older rocks (dolomites) to depths between 650 and 1,515 feet, with yields from 90 to 1,400 gallons per minute.

Land Use

Proper land use can only be realized if careful on-site investigation is completed by each proposed development site. Two engineering-geology units are present within the county. These units are those designated by Hoffman in Stout and Hoffman (1973).

Unit One - Intermediate-Thickness Residual Soil Over Carbonate Bedrock (Ca-I)

This unit is located in the eastern two-thirds of Pettis County. Bedrock consists of limestone and dolomite, with some shale. Soil thicknesses range from 0 to 40 feet but are generally less than 30 feet. Soil type is a silty clay.

Sewage Lagoons. Locations suitable for sewage-lagoon sites are those areas where there are thick soils. The quality and thickness of this soil are variable, and residual soils in the southern part are more permeable than the soils in the northern part. Frequently, permeable bedrock is encountered near the surface. Such areas should be avoided. The best areas are those with thick, silty-clay soils.

Septic Tanks. Septic-tank use should be restricted to rural settings, and even then only thick soil can be considered for use. The thin soil cover throughout most of the area will not properly filter effluent, and pollution of the groundwater supplies will likely occur when the effluent enters the porous bedrock.

Sewage Treatment Plants. Effluent discharged into some of the county's streams can be expected to enter bedrock and mix with groundwater supplies in the southeast portion of the county. In central and northeastern Pettis County, the streams are less related to groundwater as far as recharge is concerned and thus effluent discharge causes fewer problems.

Sanitary Landfills. Sites satisfactory for development as sanitary landfills can only be located by careful, on-site geologic exploration. Much of the soil cover in the southeastern part of the county and along the slopes adjoining the larger streams is too thin to prevent downward percolation of leachates. Soil for use as daily and final cover material is often available in the western and northern portions of the county.

Impoundments. Thin soil cover and permeable bedrock hinder the construction success of impoundments in portions of southeastern Pettis County. Otherwise, construction problems are routine, except in the larger bedrock-lined valleys.

Construction. No serious problems are anticipated, except for slope stability where loessial soils exist.

Unit Two - Cyclic Sedimentary Bedrock (Cy)

This unit is in western Pettis County. Bedrock formations consist of thin-bedded limestone, shale, and some sandstone. Soil is thin, usually varying from 0 to 35 feet. Soil thickness increases toward the north. Silty-clay and sandy-clay soils are present.

Sewage Lagoons. Some difficulty is experienced in locating suitable sites. In the more rugged areas, the outcropping limestone bedrock is not favorable for sewage-lagoon sites. In the less rugged areas, the gentle slopes are favorable to development; thicker soil cover is usually present, and additional borrow material for the lagoon walls can be obtained nearby. Proposed sites should be carefully investigated to determine the type of bedrock and thickness of soil cover.

Septic Tanks. Because of the thin clay soils of this unit, care should be taken in choosing septic-tank sites. The clays will not absorb large quantities of effluent, and surface pollution is likely to occur. Because of this, septic tanks should only be used in rural areas, or where the deeper soils are present.

Sewage Treatment Plants. Effluent discharged into some of the streams can be expected to enter the groundwater system. Careful investigations should be made to determine those areas where effluent discharge will have the least effect on the county's water supply.

Sanitary Landfills. Sites satisfactory for landfill development can be located without great difficulty. The gentle slopes and silty-clay soil found over much of the area are ideal for sanitary landfills. Borrow material for covering the landfill site is readily obtainable. Careful examination should be made at each proposed site to determine the depth to bedrock so that preventive measures can be taken to insure that no leachate leakage will occur.

Impoundments. Except in those areas where bedrock is exposed or lies beneath a very thin cover of soil, small impoundments can be constructed without too much difficulty. Where bedrock outcrops are widespread, leakage can be expected.

Construction. Problems encountered include poor drainage and slope failure.

* * * For additional geologic information concerning Pettis County see these selected references: 3, 6, 7, 8, 10, 11, 13, 14, 15, 16, 17, 18, 20, 21.

BOONE, CALLAWAY AND COLE COUNTIES, MID-MISSOURI REGION

Summary

Boone, Callaway and Cole Counties have a varied topography. Flat plains are present in the north, while a highly dissected plateau is present in the south. Slopes are steep in the south. Extensive floodplains are developed along the Moreau, Osage and Missouri Rivers. Relief over the area ranges from 100 to 200 feet. Numerous sinkholes are present in the south and west.

Several different kinds of bedrock are present in this study area. North of the Missouri River, dolomite, limestone, sandstone, shale and coal are found. Unconsolidated deposits of glacial till and windblown soil (loess) cover the bedrock. Soils developed by the weathering of bedrock (residual soil) include sandy, clayey and gravelly clay types. Thicknesses of these soils, windblown and residual, vary from 20 to 80 feet. South of the Missouri River, bedrock consists of dolomite and sandstone. Thick loess deposits are found adjacent to the river. Soils include sandy and gravelly clay types; thicknesses vary from 5 feet to 25 feet. There is no danger from earthquake activity.

Many scenic natural resources are found. One commercial cave is open for tours.

Mineral production is limited to stone, sand, gravel and clay. Clay and stone are plentiful and are of the greatest value at present. Coal is not mined now, but mining could resume if warranted.

Water resources are plentiful. Surface water can be obtained from the Osage and Missouri Rivers in large quantities to supply municipal use. Groundwater can be produced in sufficient quantities for both home and municipal use, depending on well depth and the aquifer utilized. Well depths vary from 100 to 1,500 feet and yield from 5 to 700 gallons per minute. The aquifers are recharged at a fairly constant rate, and increased water production can be sustained.

Development in these counties is affected by the characteristics of the bedrock and soil present, especially where soil is thin or subsoils are clay-rich. Sites suitable for sewage disposal and sanitary landfills are available throughout the area, but are more difficult to locate in Cole, southern Boone and Callaway Counties. Geologic and engineering investigation will be required before waste-disposal sites are developed, to prevent water pollution.

Similar land conditions and problems will be found in the eight counties immediately surrounding this area.

This report is not intended to supply all the geologic information needed for development in this area. It is designed to serve as a regional appraisal of the geologic features and related problems that will be encountered and as such cannot take the place of actual on-site investigation, which is recommended for any future land-use development.

Landforms and Relief

The topography of this area is varied. Smooth plains are present in northern Callaway and eastern Boone Counties. These plains have very gentle slopes, and local relief is commonly 100 feet. Total relief in the plains area is about 150 feet along Cedar Creek. In eastern Boone County, where the plains have been moderately dissected and hills have been developed, relief is commonly 125 feet. The area encompassing the southern portions of Boone and Callaway Counties and most of Cole County is typified by a highly dissected plateau. Relief is commonly 80 to 100 feet, but may be as much as 200 feet along some of the major streams. The alluvial valleys are quite wide, ranging from about a half mile along the Osage River to about 2 miles along the Missouri River. Numerous sinkholes are present in a small area about 12 miles north of Jefferson City.

Rock and Soil Formations

Several types of bedrock are exposed in this area. In Boone and Callaway Counties, the bedrock consists of dolomite, limestone, sandstone, shale and coal. Soils have been developed from the weathering of bedrock and the subsequent deposition of glacial till and windblown silts (loess). Soil types include sandy soil, clay soil and gravelly clay soil. Soil thicknesses vary greatly. Till deposits are deeper in the northern part of Boone and Callaway Counties and become thinner near the Missouri River. Loess thicknesses, however, are greatest near the river and become thinner as one progresses away from the river. Soil thicknesses range from 25 feet in the south to 40 feet in the north, but may vary locally. Soil depth in the middle of this 3-county area varies from 20 feet to 30 feet.

In Cole County, the bedrock consists of cherty dolomite and sandstone. These have weathered to produce sandy, clay and gravelly clay soils.

These soils have in turn been covered by loess deposits. Soil thicknesses range from 30 feet along the Missouri River bluffs to 25 feet in the south. Soil cover is very thin in the central portion of the county.

Alluvial soils in this Missouri River floodplain are 80 to 120 feet thick and consist of gravels and sands in the lower portion, overlain by clays and silts.

Structure and Earthquake Potential

Bedrock over most of the area is nearly flat-lying. Two anticlinal folds are present in the north. These two folds, the Browns Station anticline and the Auxvasse anticline, are the only mapped folds in the area. The strata on the southwestern side of the fold in each case are much steeper than those on the northeast. Two small faults are located about 4 miles south of Jefferson City. In Cole County about 100 feet of displacement is present at both faults. There is no record of recent earthquake activity within the region and future earthquake activity is not anticipated.

Scenic Natural Resources

Many caves and natural bridges are found in Boone, Callaway and Cole Counties. These caves and bridges are quite scenic and are of interest to many people. One hundred-three caves have been reported in this area, with most of them being in Boone County. Boone Cave, in Boone County is commercially operated.

Natural bridges and tunnels are common in areas of this type. Rock Bridge in Boone County and Natural Bridge Cave in Cole County are the only natural bridges reported to date in this three-county area.

The Pinnacles is an impressive natural feature north of Columbia in Boone County. Formed by erosion, the Pinnacles were created when two creeks, Silver Fork and Kelley Branch, carved their valleys into bedrock, leaving this 800-foot-long blade of limestone between them.

Mineral Resources

Several economic mineral deposits occur in Boone, Callaway and Cole Counties. Coal, stone and clay are the most valuable known resources, and production should increase with the anticipated population growth of the area.

Lead and Zinc. Production of lead and zinc ores ceased in 1947. The lead and zinc mineralization was often associated with barite and was usually found in mineralized filled-sink structures or in small veins. Very little known reserves exist and the amount still available is insignificant when compared to the deposits of southeastern Missouri. Future production is unlikely unless additional deposits are discovered.

Barite. Beginning in 1910, Cole County was a leading barite producer in the Central Barite District. Significant production ended in 1969, however. These ores were found in circle-type or filled-sink deposits and are now practically depleted. Future production is unlikely unless additional mineralized filled-sinks are found. Barite from this area was of chemical-grade and commanded a higher price than barite used for drilling muds. Barite mined from similar deposits in Benton County is used for manufacturing paints.

Stone. Limestone is quarried at nine locations within the three-county area. Four quarries each are located in Boone and Callaway Counties, and one quarry is in Cole County. Stone produced is used for concrete aggregate, road metal, railroad ballast, aglime, and rip-rap. Adequate stone reserves are present in southern Boone and Callaway Counties and Cole County.

Clay and Shale. The Columbia Brick and Tile Company at Columbia produces face brick from Pennsylvanian clays and shales. Substantial reserves of clay and shale suitable for brick manufacture are present in the region. Refractory-grade clays are quarried in Callaway County by two companies, the Harbison-Walker Refractories Company and the H. K. Porter Company. These clays (plastic, flint, and burley) are used to manufacture refractory products. Reserves of these clays are adequate for the next 25 years.

Sand and Gravel. Sand and gravel are currently produced from floodplain and in-channel deposits of the Missouri and Osage Rivers. Three sites in the region are in production. Two plants in Boone County are on the Missouri River and one plant is on the Osage River floodplain in Cole County. Sand is produced for such uses as fill, railroad ballast, and construction. Reserves are considered to be unlimited.

Coal. There has been substantial production from this region in past years. The region's most important coal deposit is the Bevier coal bed in Boone and Callaway Counties. In northwestern Boone County, the Summit coal is also present. Strip mining of coal recently ceased in this region with the closing of the Mark Twain mine. Considerable reserves remain but reopening of the area's mines will depend on the increased demand for fuels.

Water Resources

Surface water and groundwater are both available for use in the Jefferson City area.

Surface Water. The entire area is drained by the Missouri River and the Osage River and a smaller stream, Cedar Creek, drains an area north of the Missouri River. The combined flow of these streams is such that vast quantities of water pass through the area daily. Large quantities of water would be available for public use along the two larger streams, and surface impoundments could be constructed along tributary streams to serve the needs of small municipalities and water-supply districts.

Surface-water quality varies seasonally in all of the streams in the study area. It also varies from stream to stream because of the size of the drainage basin, sizes of the streams, rock type underlying the drainage basin, and the quantities and types of effluent being introduced upstream from the point of study. In all instances, by state regulations, filtration and chlorination are required before surface-water can be used for public water supplies.

Groundwater. A distinction is made between bedrock aquifers and alluvial aquifers in this area to facilitate discussion.

Bedrock aquifers. The rocks in the study area dip toward the north. Older rocks are exposed at the surface in the southern part of the area and younger rocks are exposed at the surface in the northern part of the area. Rocks of different ages with different hydrologic characteristics are discussed separately. That part of the area south of the Missouri River is treated as one hydrologic area while that part at the north of the Missouri River as another hydrologic area.

Shallow domestic wells constructed south of the Missouri River range in depth from just over 100 feet deep to approximately 375 feet deep. Geologic formations penetrated by these shallow wells consist of cherty dolomites and sandstones. Of these, only the lowermost formations have consistent water-bearing characteristics. Yields of shallow wells range from a few gallons per minute to more than 30 gallons per minute. The cherty dolomites locally yield small quantities of water to wells in the area, but the reliability of these units is subject to rainfall and recharge patterns in the area.

Shallow domestic wells constructed north of the Missouri River range in depth from less than 100 feet to approximately 500 feet. Geologic formations of various ages are penetrated by these wells and include glacial drift and residual material, limestones, dolomites, sandstones and shales. Reliability of these units as aquifers is subject to rainfall and recharge patterns in the area, and could, therefore, be subject to failure during extended dry periods. Yields of wells penetrating these units may range from just a few gallons per minute to in excess of 30 gallons per minute.

Deeper wells constructed south of the Missouri River range in depth from 600 to more than 1,500 feet. Usually these deeper wells are constructed as state-approved or public-supply wells, and the shallow water-bearing zones are cased out. This casing is pressure-grouted with cement, and in all instances the bottom of the casing is set at least below the Roubidoux Formation. The geologic formations which may be utilized as aquifers include Cambrian and Lower Ordovician sandstones, sandy dolomites, and dolomites. All of these aquifers yield fairly large quantities of water, with the Potosi Dolomite being the most prolific. Yields of wells obtaining water from these deeper aquifers range from 50 gallons per minute to more than 700 gallons per minute, with the larger yields coming from wells penetrating the Potosi Dolomite.

Deeper, higher-yielding wells north of the Missouri River penetrate aquifers discussed above. Yields are from 100 gallons per minute to as much as 870 gallons per minute.

Long-range effects of the cumulative pumping of these deep wells have begun to be felt in the study area. Pumping levels in certain high-capacity wells in the Jefferson City area (Cole and Callaway Counties) have been lowered, locally, as much as 100 feet. This will continue with increased pumping resulting from more wells, higher water demands and the like and may mean increased costs for water due to increased electrical demands and larger pumps. It does not mean that the water is being "mined" and that it will eventually be depleted. The aquifers in the study area and in adjacent areas are recharged by precipitation. If all groundwater withdrawal ceased, the water levels would return to the "prepumping" level in a very short time.

The quality of water from bedrock wells in the area is excellent. Very little difference in chemical quality can be noted between shallow and deep groundwater sources, although total dissolved solids tends to be slightly higher in water from deeper zones.

Water from the deeper horizons tends to be mineralized (salty) in the extreme western and northwestern part of Boone County. To the west and northwest of the area, the deeper zones yield highly mineralized water. The fresh water-mineralized water boundary is not a distinct line or boundary, but a gradational one. With increased pumping from the deeper aquifers, it is quite possible that this indistinct boundary will migrate to the southeast, and salt-water encroachment may occur in areas which now yield fresh water.

Alluvial aquifers. The unconsolidated sands, gravels, clays and silts underlying the floodplains of the area's major streams are a major source of groundwater. These deposits range in thickness from zero to as much as 150 feet. Where they are of sufficient thickness and contain relatively coarse, clean sand and gravel, yields as high as 1,000 gallons of water per minute are possible. The City of Columbia, in Boone County, is presently developing a well field in the alluvium of the Missouri River.

Wells drilled into this material can have a wide variety of constructions ranging from shallow, driven or sandpoint wells to large-diameter (48-inch) gravel-packed, screened wells. Yields, of course, depend on the well size (diameter) and the depth.

Because of the relatively free interchange with the streams, the water levels in these deposits respond rather quickly to changes in their stage.

Alluvial waters are usually of good chemical quality but tend to have higher iron concentrations than waters from bedrock sources. In many instances these concentrations are high enough to make some sort of treatment necessary.

Land Use

Conditions for proper land use vary with respect to bedrock-soil units. A variety of geologic conditions exist in Boone, Callaway and Cole Counties so each area much be considered separately. The various facets of geology should be considered including bedrock, soil, structure and water resources.

Unit One - Thin Glacial Soil Over Cyclic Bedrock (Gl-Cy)

This unit, in northern Boone and Callaway Counties, consists of glacially derived soils over cyclic bedrock. The bedrock is thin limestone, coal, thick sandstone and shale. The soil cover is generally 40 feet thick and consists of silty clays. Permeability is low because of the high clay content. Where thick limestone beds are present, the soil is usually more stony and more permeable. The more common problems associated with this unit are poor slope stability and poor permeability.

Sewage Lagoons. Accommodation of wastes in sewage lagoons can best be dealt with where the soil cover is thick enough and has a high clay content, or where the bedrock is shale. Locations where limestone, coal or sandstone crop out should be avoided.

Septic Tanks. In this area the lack of absorbency of the clay soils will cause unfiltered septic-tank effluent to surface and create surface pollution problems. Septic tanks should therefore be restricted to those areas where adequate acreage is available or where the soils have greater permeability.

Sewage Treatment Plants. Satisfactory discharge points can be located within this unit. Stream valleys are underlain by either tight bedrock, such as shale, or by impermeable clay soils. In this area stream flow is persistent and water loss to bedrock is negligible. Problems may exist during periods of little or no precipitation because of inadequate dilution.

Sanitary Landfills. Suitable landfill sites are numerous. Ideal locations exist in strip-mined areas where coal has been removed. Utilization of these old strip mines will also facilitate land reclamation. Wet areas and mines with inadequate soil available for cover should be avoided.

Impoundments. Small farm ponds can be constructed in areas where tight clay soils or shales are present. Larger lakes may be constructed along creeks in areas where water loss to bedrock is small.

Construction. Site investigation will be necessary before roads and larger buildings are constructed. Problems are encountered because of poor slope stability and poor drainage characteristics of the soil. Also, some road maintanence problems will arise during the winter season because of freeze-thaw breakup.

Unit Two - Thin Glacial Soil Over Carbonate Bedrock (Gl-Ca)

This unit, in northern Boone County has bedrock that consists primarily of massive, permeable limestone. Soil is silty clay mixed with stones and it is generally less than 40 feet thick.

Sewage Lagoons. Sites satisfactory for development as sewage lagoons are somewhat difficult to locate. The variable thickness of soil over pinnacled carbonate bedrock will in many cases allow seepage of effluent into bedrock and cause groundwater contamination.

Septic Tanks. Only those areas with soil cover can be safely utilized. Because of the relative impermeability of the soil surface, pollution may occur. Septic tanks should be used only where thick soils and rural conditions exist.

Sewage Treatment Plants. Treated effluent should not be discharged in this unit. Contamination of groundwater is likely to occur through the many caves and sinkholes present in this unit.

Sanitary Landfills. Ideal sites for development as sanitary landfills can be found. Narrow gulleys can be utilized. If bedrock is encountered during excavation, it will be necessary to over-excavate approximately two feet of rock and bring back to grade with packed clays. Small diversion levees may be necessary to protect the landfill from flooding.

Impoundments. No serious problems are anticipated in choosing a site suitable for development. Areas with sinkholes should be avoided or leakage may occur.

Construction. Major problems that might be encountered include variable depths to bedrock, karst, and poor internal soil drainage.

Unit Three - Carbonate Bedrock With Some Shale (Ca-Sh)

This unit, in southeastern Boone and southern Callaway Counties, is an area of massive limestone outcrops on rugged hillsides. Soil cover is thin and permeable. Leakage into bedrock is a significant problem.

Sewage Lagoons. The locating of sewage lagoons in this unit is difficult because of the thin soil cover, bedrock outcrops and rugged hillsides. The presence of bedrock in a lagoon floor is a problem because leakage into the groundwater system may pollute nearby shallow wells. Small creek valleys should also be avoided. These valleys are so narrow that flood waters may destroy lagoons causing pollution of downstream waters or nearby groundwater.

Septic Tanks. Because effluent from septic tanks can enter rock fractures in the area, only those places where fairly deep soils are present should be considered. Unfiltered effluent will cause water pollution problems.

Sewage Treatment Plants. Suitable discharge points are very difficult to locate. Problems are encountered because of: 1) leakage into underlying bedrock, 2) non-persistent stream flow, 3) inadequate dilution and 4) possible pollution of water in the immediate area.

Sanitary Landfills. Suitable landfill sites can be located with some difficulty. Areas that can be utilized are those isolated sites away from the Missouri River where soil cover is relatively thick. Also, some sites can be located in central Callaway County where relatively impermeable shales and shaley limestones are present. There are some sinkholes in the western portion of this unit which should not be used as sanitary landfills. Site investigation is required.

Impoundments. Small farm ponds can be located in shale bedrock or in thick, impermeable clay soils. Ponds located in areas with sandstone and limestone outcrops will not retain water while larger impoundments along creek valleys may lose water into the permeable bedrock.

Construction. No major construction problems are anticipated. Site-selection investigation is recommended.

Unit Four - Karst (Ca-K)

This unit, in southwestern Boone County, is typified by numerous sinkholes and caves. There is little or no surface drainage because of this karst development. The bedrock consists of permeable limestone. Liquid wastes from septic tanks, sewage lagoons, treatment plants and sanitary landfills can readily enter the groundwater system through these solution features. The polluted water is then likely to be pumped to the surface by domestic wells or it may resurge at a spring at a lower level. Developments such as waste disposal sites therefore require detailed geological and engineering site investigations and preparation.

Unit Five - Intermediate-Thickness Residual Soil Over Carbonate Bedrock (Ca-I)

This unit, in northern Cole County, is an area of cherty-dolomite bedrock that has weathered to produce a thin, gravelly clay soil over most of the area.

Sewage Lagoons. Suitable sites can be located with some difficulty. In general soil cover is thin and hinders lagoon construction, except on the more moderate slopes where deeper soils have formed. Bedrock excavation should be avoided unless clayey soil is available to pad the lagoon floor. On steeper slopes and in valleys where soils have been removed by erosion, it is very difficult to locate satisfactory sites. Lagoons excavated into thin soil cover on steep slopes will leak horizontally into the cut slope. Sites such as these are difficult to seal.

Septic Tanks. The disposal of waste material by using septic tanks presents a serious problem in this region because of the thin soil cover. The thin soils do not properly filter effluent, and the still-polluted materials will degrade water quality in the area.

Sewage Treatment Plants. Ideal sites for sewage treatment plant discharge can be located with some difficulty. On-site investigations are mandatory to determine those areas where contaminants will not enter the groundwater system. These sites are usually in stream valleys where there is sustained flow to properly dilute the treated effluent.

Sanitary Landfills. Locating sites suitable for landfill development is difficult. Much of the area does not have adequate soil cover although soil cover may be deep enough on gently sloping hillsides. Site-selection investigation is mandatory.

Impoundments. Small farm ponds can be constructed where soil thicknesses are adequate. Gently sloping hillsides are best. Larger impoundments can be located in creek valleys where there is sustained flow, but some leakage is likely to occur.

Construction. No problems are anticipated in most of the area. Site investigation is necessary, however, if steep slopes are to be properly utilized.

Unit Six - Intermediate-Thickness Residual Soil Over Sandstone Bedrock (SS-I)

This unit, in southern Cole County, is an area of thick sandy and stony-clay soil over sandstone and sandy-dolomite bedrock.

Sewage Lagoons. This unit is unsuitable for sewage lagoons because of: 1) ruggedness of terrain, 2) sandy horizons, 3) narrow and steep valleys and 4) flooding waters. It is recommended that sewage lagoons not be constructed here.

Septic Tanks. These can be safely utilized only where there is thick soil cover. Steep slopes should be avoided. To avoid pollution problems, septic tank use should be restricted to rural and small-village settings.

Sewage Treatment Plants. These can be safely utilized only in those valleys with permanently flowing streams. In areas where streams cut into sandy horizons, water loss can be expected and pollutants may enter the groundwater system and pollute nearby wells.

Sanitary Landfills. Few sites are suitable for landfill development although small sites on ridge tops may possibly be used. Subsoil exploration is necessary to determine if adequate fill material is available.

Impoundments. Sites suitable for farm ponds exist only on ridge tops. Larger impoundments will have leakage problems into valleys of permeable bedrock.

Construction. Problems may be encountered because of the steep slopes. Ridge tops offer the best sites for development.

Unit Seven - Alluvial Soil (Al-Tu)

This unit is present along the Missouri River, Moreau River and lower Osage River valleys. The alluvial soil consists of a mixture of gravels, sands, silts and clays. It is unsuitable for septic tank and sanitary landfill development but adequate sites may be found for sewage lagoons and sewage treatment plants. Flooding is a serious problem. Areas with sandy soils should be avoided because leakage into the groundwater system may result.

* * * For additional geologic information concerning Boone, Callaway and Cole Counties see these selected references: 3, 6, 7, 8, 10, 11, 13, 14, 15, 16, 17, 18, 20, 21.

FRANKLIN, JEFFERSON, LINCOLN, ST. CHARLES AND WARREN COUNTIES

(Limited to the General Boundaries of Sensitive Area #2)

Summary

Franklin, Jefferson, Lincoln, St. Charles and Warren Counties have varied topography, ranging from smooth plains to rugged hills. Total relief in this area is about 300 feet.

There are many different kinds of bedrock and the soils that have developed on bedrock are just as varied. Both cherty limestone and cyclic (limestone, sandstone, shale) units are found north of the Missouri River. In the south, dolomite, cherty dolomite, limestone, sandstone and shale are found. Soil varies from a clay type in the north to sandy or gravelly clay in the south. Variations will depend on the parent bedrock. Permeable, sand-gravel-rich deposits are also widespread.

The most recent earthquake tremors were felt in 1945. Future earthquake activity is not anticipated.

The mineral resources of this area are varied, and considerable resources are present. Iron, lead and zinc are no longer produced in this area, but additional ores could be present. The most valuable resources are stone, sand and gravel, and clay.

The five-county area derives its water needs from both surface and groundwater. Approximately 98 percent of the area's water needs are supplied by surface water from major streams. Chemical quality of this water is good; however, treatment is required by law. Many small towns obtain their water supplies from the groundwater system. Wells may yield from 50 to 500 gallons per minute, depending on the aquifer utilized. Chemical quality ranges from good to poor.

Proper land use will entail careful on-site investigation to determine the geologic factors that will influence land developments. The choice of an unsuitable site for waste disposal will most likely lead to groundwater or surface-water pollution, in addition to the problems involved in either correcting the problem on-site or relocating the waste disposal area.

Similar land conditions and development limitations can be found in the eight counties adjacent to this study area.

This report is not intended to provide all the information needed for geologically oriented development in this five-county region. It is intended to serve as an appraisal only and cannot take the place of actual on-site investigation, which is recommended for any future land-development project.

Landforms and Relief

The topography of this area is varied. Plains are well developed in Lincoln, northern Warren and St. Charles Counties and in isolated areas in southwestern Franklin and northeastern Jefferson Counties. In St. Charles, Lincoln and northeastern Jefferson Counties, the plains are moderately dissected by many streams. Relief is commonly 300 feet. Valley widths range from ½ to 1 mile. In central Warren County these plains are much less dissected, and relief is usually about 100 feet. Floodplains are generally 1/5 to 1/2 mile wide. The area in southwestern Franklin County is typified by rolling plains. Relief is commonly 150 feet, and the valleys are usually narrow.

The southern halves of Warren and St. Charles Counties and the remaining areas in Franklin and Jefferson Counties are typified by rugged terrain. Streams have dissected the former plateau-like area, and long ridge-like hills have developed. Bluffs as high as 150 feet are common along the major streams, while relief in this highly dissected area is about 250 feet. Valleys of the Bourbeuse, Meramec and Big Rivers range from 1/5 to 1/2 mile wide. Sinkholes are common.

The alluvial lowlands of the Mississippi, Missouri and lower Meramec Rivers are very wide and have little relief. Those areas with the greatest relief are the terraces formed by retreating glaciers.

Rock and Soil Formations

The bedrock formations of this five-county region are varied. Major rock types are limestone, dolomite and sandstone. Shale and coal are less abundant.

North of the Missouri River in southern Lincoln County and northern Warren and St. Charles Counties, outcrops of thick, cherty limestone predominate. In southern Warren and St. Charles Counties, thick sandstone and thick, cherty dolomite bedrock are predominant. Minor amounts of shale and coal are also present. Soil cover is well developed over the entire region. Thick deposits of till were laid down by retreating glaciers and loess was later deposited on the till. Soils, developed by the weathering of bedrock, till and loess deposits, are extremely varied. Soil types include clayey and clayey, gravelly soils in areas underlain by dolomite, sandstone or shale. Thicknesses range from 20 to 200 feet, with the thicker soils in areas covered by glacial till.

South of the Missouri River the bedrock formations are more varied than in the north. Thick, cherty dolomites, shaly dolomite and sandstone predominate. Limestone and shale are common in northeastern Jefferson County and isolated clay deposits are found in Franklin County. Because this area was south of the retreating glacier, no glacial till was deposited. Loess (a windblown silt) was deposited, however. Soils are well developed, and their variability reflects the character of the parent rock material. Soils include sandy-clay and gravelly-clay types with thicknesses ranging from 0 to 100 feet.

Alluvial deposits in the Mississippi and Missouri River valleys consist of an admixture of gravel, sand, silt and clay in varying proportions. Thicknesses range from 80 to 100 feet. In the valleys of the Meramec, Bourbeuse and Big Rivers, thickness ranges from 20 to 40 feet.

Earthquake Potential

The rock formations in this five-county region are, for the most part, flat-lying. Dips range from 0 degrees to 5 degrees, except in a severely faulted area in Jefferson County, where dips may be as great as 72 degrees in the Valles Mines-Vineland fault zone.

There are several major folds mapped in the area, but in each case strata dip gently away from the axes.

Many faults have been mapped in the region and bedrock displacements range from very little to several hundred feet. The most recent earth tremors reported in the region occurred in 1945 in the Moselle area of Franklin County. The Moselle fault was near the epicenter of this earthquake activity. No damage was reported.

Future earthquake activity is not anticipated.

Scenic Natural Features

Caves and springs are common in the five-county area. Four "big springs" in Franklin County are Falling Spring and Elm Spring in Meramec

State Park, and Roaring Spring and Kratz Spring near Stanton. These springs each have a minimum flow of 50,000 gallons per day and a combined flow of approximately 7 million gallons per day. Kratz Spring is the largest, with nearly 5 million gallons per day.

There are 184 caves in the region. Two of these caves, Fisher Cave and Meramec Caverns in Franklin County, have been developed and are now commercially operated. There are many undeveloped caves in Meramec State Park.

Mineral Resources

The mineral deposits of this five-county area are substantial and varied. Metallic minerals have been mined in the past, and the potential exists for future development. Nonmetallic minerals are by far the area's most valuable resource, and an extensive quarrying industry has been established.

Iron. The area is a potential producer of iron ore since it has prominent magnetic highs and the presence of iron ore has been confirmed by exploration. Development of these ore bodies will depend on the extent of mineralization and economic conditions.

Lead and Zinc. Production of lead and zinc ores has been limited to small, shallow deposits in Franklin and Jefferson Counties. The potential for deep mineralization similar to that in the Southeast Missouri Lead district is unknown.

Barite. Small barite deposits are found near the Big River in Jefferson County and in isolated areas in southwestern Franklin County. Barite was mined in small quantities in Jefferson County until 1961. A new barite mill will soon be in operation near the Big River in Jefferson County.

Stone. The area is a major producer of crushed and broken limestone and dolomite. The stone is used for concrete aggregate, asphaltic paving, road metal, aglime, rip-rap and cement manufacture. Quarried units include Mississippian and Ordovician-age rocks. There are adequate resources of stone, but urbanization and zoning may restrict development of some deposits.

Sand and Gravel. Sand and gravel, primarily for construction use, is obtained by dredging from in-channel deposits of the Missouri and Mississippi Rivers and is also obtained from glacial outwash deposits in Lincoln County.

Clay and Shale. Fireclay deposits in Warren and Franklin Counties have been mined in the past, and continued minor production is expected. in the two counties. Deposits range from less than an acre to several acres in extent, and depths vary from a few feet to 50 feet or more. Mining is by open pit.

Structural-clay-products plants are not present in the area, although some clay and shale suitable for brick manufacture are present. Shales in eastern Lincoln County and central St. Charles County are suitable.

Silica Sand. Silica-sand plants in St. Charles and Franklin Counties are active. Silica sand is produced for the manufacture of glassware, abrasives, metallurgical silica and ceramics. Substantial reserves are present in Jefferson, Warren, St. Charles and Franklin Counties.

Coal. Thin and irregular seams of coal are present within Pennsylvanian rocks in the area, and some minor past production has been reported. Reserves of mineable coal are negligible, however, and future coal mining is not expected.

Water Resources

Water supplies in the study area are available from streams and from bedrock and alluvial aquifers.

Surface Water. The region is well drained by the Missouri River and its tributaries and by the Mississippi River and its tributaries. The Meramec River, in the southern part of St. Louis County, is an important surface-water source also. Approximately 82 percent of the water used in this area is from the Mississippi River and about 15 percent is from the Missouri and Meramec Rivers. Most of this pumpage is used for cooling and for generating electric power. Bedrock and alluvial aquifers account for only 1 and 2 percent of the total pumpage.

Quality of these surface-water sources varies from good in some tributary streams to very poor in highly urbanized or industrialized areas. This surface water requires extensive treatment for most uses.

Groundwater. Bedrock aquifers are composed primarily of dolomite and limestone, with scattered sandstone horizons. More than 20 towns in seven rural water districts are served by these aquifers as are most domestic users in the area. Well yields ranging from 50 gallons per minute to as much as 500 gallons a minute can be developed in bedrock aquifers in the western third of the study area and in the southwestern part of Jefferson County.

Quality of water from bedrock aquifers ranges from good to poor with the deeper bedrock horizons becoming increasingly mineralized to the east of the western margin of the study area. These rocks dip or tilt at approximately 65 feet per mile and are encountered at greater depths on the east than on the west. This mineralization takes the form of high total dissolved solids, high chlorides and high sulfates.

Water can be encountered in the shallower horizons throughout most of the study area. However, due to the heavy urbanization in this area, these wells are subject to contamination, and in many instances large areas are already experiencing rapid deterioration of groundwater quality.

Floodplains of the Mississippi and Missouri Rivers have the greatest potential for development of the groundwater. Yields of more than 3,000 gallons per minute have been reported in the Mississippi River floodplain in St. Charles County, and the Missouri River floodplain has wells yielding as much as 2,500 gallons per minute. Yields from the Meramec River floodplain have been reported to be as much as 500 gallons per minute.

Except for local areas where upward leakage of the mineralized bedrock water is occuring, the water from the alluvial deposits is very good. It is generally a very hard, calcium-magnesium bicarbonate water and the iron and maganese content is commonly high. This water would require a minimum of treatment.

Land Use

Proper land use entails utilization of the disciplines of geology and engineering. On-site investigations of proposed development sites are needed to determine bedrock and soil characteristics, water resources and rock structure as a basis for deciding the feasibility of each proposal. The rock and soil deposits in this area can be divided into eight engineering geology units. These units are chosen without regard to the various geologic ages of the deposits and merely indicate that a similarilty in geologic problems exists in a particular area.

Unit One - Variable Soil Thickness Over Carbonate Bedrock (Ca-V)

This unit is in eastern Lincoln, central St. Charles and northeastern Jefferson Counties. Limestone bedrock in this area is thick-bedded. Karst features are developed with solution channels, caves and sinkholes being common, especially in the northern part. The soils are highly varied and range from a loessial clay soil to a residual clay soil , depending on the amount of loess present. The residual clay soils are generally impermeable.

Sewage Lagoons. In portions of this unit, lagoons can be built satisfactorily, and little or no treatment is necessary to insure liquid retention. Loess near the river bluffs may have to be sealed with bentonite to prevent leakage. In the northern portion of the unit, karst features hinder the safe use of sewage lagoons. Careful site investigations are recommended before lagoons are constructed anywhere in this unit.

Septic Tanks. The use of septic tanks should be restricted to rural and farm settings. Because of the thin soils, septic-tank effluent generally is not filtered satisfactorily and often surfaces and causes pollution. Where thin loessial soils overlie bedrock there may be seepage into the bedrock and groundwater may be polluted. In the north, sinkholes will be a major problem because of their direct connection with the groundwater system. Septic tanks can be safely used on plots of 3 acres or more, but site investigation is strongly recommended to insure that no significant leakage occurs.

Sewage Treatment Plants. Sites suitable for the discharge of sewage-treatment-plant effluent can be located. Treatment plants should be located near large, gaining streams preferably those having a sustained flow. Losing streams are not suitable because the water loss to bedrock, indicates that effluent could reach the groundwater system.

Sanitary Landfills. Satisfactory landfill sites are difficult to locate. Areas with deep loessial clay soils are best. Deep ravines in this soil cover can be utilized with proper engineering and the land can be reclaimed for recreational use at the same time. Landfills should not be utilized in karst areas. Sinkholes are usually directly connected to the groundwater system and pollution of an area's groundwater supply is likely.

Impoundments. Sites for small farm ponds can be located without difficulty in much of this unit; however, in karst areas some problems with leaking ponds may occur. Larger ponds or lakes should be constructed in valleys where there is sustained flow for most of the year.

Construction. No problems are anticipated, except in those areas where karst is found. Sinkholes, because of their function as natural drains, should be developed only after a thorough geologic investigation is completed. Engineering design will be, by necessity, elaborate.

Unit Two - Thin Glacial Soil Over Carbonate Bedrock (Gl-Ca)

This unit is in southeastern Lincoln, northern Warren and western St. Charles Counties. Bedrock is massive limestone and soil cover is generally a clayey or stoney clay soil that varies in thickness. Karst features such as caves, sinkholes, pinnacles and solution channels are common.

Sewage Lagoons. Lagoon sites can be located with some difficulty. The thick glacial soils are suitable except in the more rugged areas where stony soils exist. In areas where karst is a problem, lagoons should not be built because collapse and pollution of the groundwater supply could occur.

Septic Tanks. The use of septic tanks should be restricted to rural and farm areas 3 acres or larger. Soils in this unit are generally not very permeable and a larger-than-usual waste field is necessary to insure proper filtration of the effluent. In areas where karst prevails, septic tanks should drain away from sinkholes to avoid groundwater pollution.

Sewage Treatment Plants. Suitable treatment-plant sites may be difficult to locate. Discharge should only be into those streams with sustained flow. Streams that flow only part of the year or losing streams are not acceptable because of the problems associated with karst terrain.

Sanitary Landfills. Satisfactory sites can be located with little difficulty and thick loessial soil is available to serve as cover material for the landfill. In karst areas, landfills should not be near any sinkholes since there could be leakage into the groundwater system.

Impoundments. Small farm ponds can be constructed with little difficulty in areas unaffected by karst.

Construction. Minimal problems are anticipated in areas unaffected by karst.

Unit Three - Carbonate Bedrock With Some Shale (Ca-Sh)

This unit is in northeastern Franklin and northern and eastern Jefferson Counties. Bedrock is predominantly carbonate with some shale and sandstone. The soil cover varies with the type of bedrock it overlies and thickness is usually less than 30 feet. Proposed development sites should be investigated before being put into use.

Sewage Lagoons. Satisfactory lagoon sites are not difficult to find. In most cases remedial work is not necessary. In areas with several types of soil, it may be necessary to seal the lagoon floor with bentonite to insure effluent retention until oxidation occurs.

Septic Tanks. The success of a septic tank varies greatly depending on the type of soil. Site investigation is recommended to determine the feasibility of each proposed site, and to identify soil types and to establish the proper number of acres per septic tank.

Sewage Treatment Plants. Many of the streams in this unit are losing streams and as such could transmit effluent into the groundwater system. Discharge should be restricted to streams with persistent flow, such as the Big River or Meramec River.

Sanitary Landfills. Suitable landfill sites are difficult to locate. Only small sites for landfills may be available. Preferably, each site to be utilized should have at least 20 feet of soil between the floor of the fill and bedrock.

Impoundments. Impoundments can be constructed with few problems in the smaller creek valleys. The overexcavation of soil from within the lake area to obtain soil for dam construction is not recommended. This will cause severe leakage.

Construction. Few problems are encountered here although steep slopes may settle and sliding may occur.

Unit Four - Intermediate-Thickness Residual Soil Over Carbonate Bedrock (Ca-I)

This area is in southern Warren, Franklin and southern Jefferson Counties. Bedrock formations consist of thick-bedded dolomite. Soil cover, a residual clay, is generally 40 to 60 feet thick. Karst features are developed. Dry stream valleys and streams with unusually low-flow characterize the area and indicate the presence of underground channels. Discharge of pollutants into any of these channels presents a threat to water quality.

Sewage Lagoons. Lagoons can be satisfactorily located within this unit if measures are taken to insure that lagoon waters will not permeate into the groundwater system. Most lagoon sites require remedial measures to make them usable. Remedial work may entail lining the lagoon with an impermeable clay such as that on ridge tops and slopes in the area.

Septic Tanks. Soils are generally quite stony and permeable. Because of this, the soil layer beneath the septic tank and above bedrock will be saturated after a number of years, causing effluent to enter the groundwater system without being filtered. Septic-tank use is therefore recommended only for rural areas.

Sewage Treatment Plants. Treatment plants should be located so that discharge of treated effluents will be into gaining streams or into those with persistent flow. The Meramec, Bourbeuse and Big Rivers could support sewage-treatment plants.

Sanitary Landfills. Small landfill sites can be located here, but most of them should be restricted to colluvial slopes where there are sufficient impermeable soils to impede the flow of leachates into bedrock. Many of these locations, however, would be too small to fulfill the needs of a large city.

Impoundments. Small farm ponds can be constructed on ridge tops and colluvial slopes where sufficient impermeable soil cover is present. Large impoundments will have problems because of leakage to bedrock.

Construction. No construction problems are anticipated except on steep slopes, where sliding may occur.

Unit Five - Shallow Residual Soil Over Carbonate Bedrock (Ca-S)

This unit is in southeastern Franklin and southern Jefferson Counties. Bedrock consists of medium-bedded dolomite and soil thicknesses range from 0 to 10 feet. The clay soil is relatively impermeable.

Sewage Lagoons. Satisfactory sewage lagoon sites are difficult to find because of the thin soil cover. In some cases, bentonite can be used to prevent leakage. Areas with thicker soils can be utilized satisfactorily.

Septic Tanks. Septic tanks should be used only in rural settings. The soils are too thin and impermeable to properly filter the effluent in most cases, and both surface and groundwater pollution are extremely likely.

Sewage Treatment Plants. Sewage treatment plants should only be used in conjunction with gaining streams such as the Big River.

Sanitary Landfills. Satisfactory landfill sites are difficult to locate because of the thin soil cover. Sites that can be utilized for landfills are generally small and could not satisfy the needs of a large town or city.

Impoundments. Small farm pond sites are easily located. Large impoundments can be built in some large creeks that have sustained flow. Soil for construction may not be adequate.

Construction. No problems are anticipated except in areas with steep slopes, where sliding may occur.

Unit Six - Carbonate and Cyclic Bedrock (Ca-Cy)

In southwestern and central Franklin County, the bedrock consists mainly of shale and sandstone, with some limestone. Silty, gravelly clay soils range in thickness from 10 to 30 feet and in some cases, are even less. Some ancient sinkholes are filled with fire clay. These soils generally have low permeability, except where they are sandy.

Sewage Lagoons. Satisfactory lagoon sites can be found without too much difficulty. The biggest problem is leakage but soils that are too permeable can be treated with bentonite sealant. In those areas where the soils are more impermeable, there should be no difficulty in sealing the lagoon.

Septic Tanks. Where cyclic deposits are predominant, septic tanks can be used in light urban areas and farms, where 3 acres or more per lot are available, depending on the depth of soil cover.

Sewage Treatment Plants. Treatment plant sites can be easily located because of most of the streams here are gaining. The capacity of the streams to accept treated effluent should be determined by the Missouri Clean Water Commission.

Sanitary Landfills. Satisfactory landfill sites can be located, but those areas where fireclay has been mined are especially good. Deep clay pits are excellent sites and can handle the refuse from many communities. If the clay pit encounters groundwater it should not be used, however.

Impoundments. Both small farm ponds and large lakes can be constructed.

Construction. No construction problems are anticipated.

Unit Seven - Karst (Ca-K)

This unit is in eastern St. Charles and western Lincoln Counties. The bedrock which consists of permeable limestone has a very irregular surface even over short distances. Caves, sinkholes and pinnacles, known collectively as karst, are common features. A highly variable, stony, red clay soil covering the limestone bedrock varies in thicknesses from 0 to more than 100 feet.

Sewage Lagoons. Suitable sites are difficult to locate because of unfavorable bedrock and soil conditions. Where soils are thin, leakage to bedrock may occur and pollution of the groundwater system might easily happen. Soils in this unit are very permeable; lagoon sites may require clay padding or bentonite to prevent leaks. The use of sewage lagoons should be discouraged.

Septic Tanks. Septic tanks should not be located in karst areas where drainage can enter sinkholes. Drainage fields should be located on ridges, so that effluent will be filtered before entering the groundwater system.

Sewage Treatment Plants. Suitable discharge points may be difficult to find. Unless effluent is discharged into a stream with sustained flow, insufficiently diluted effluent may enter the groundwater system.

Sanitary Landfills. Sinkholes should not be used for landfills because of their direct connection with the groundwater system. For similar reasons, landfills should also be avoided where there are thin soils, or where bedrock is exposed. In general, most of this area is not suitable for sanitary landfill development. Any site proposed for development should be thoroughly investigated by a geologist.

Impoundments. This unit is suitable for small farm ponds in those areas where thick clay soils are present. These ponds can be constructed to there will be little leakage.

Construction. Development in sinkholes or sinkhole drainage fields should be discouraged to avoid disrupting the movement of surface water toward these natural drains.

Unit Eight - Carbonate Bedrock With Some Sandstone (Ca-Ss)

This unit is in southern Warren and southern St. Charles Counties. Bedrock consists primarily of thin-bedded carbonates, with some sandstone. Soil cover varies in composition horizontally and vertically. Clayey, silty and clayey silt soils are common.

Sewage Lagoons. Suitable lagoon sites are difficult to locate. The difficulty arises, not because of the quality of the soils, but because the quantity of soil available is often insufficient. Soils are frequently shallow in the northern part of this area, but they are usually thick enough in the southern portion. When excavating for a shallow lagoon site, bedrock is often exposed. Another difficulty arises in karst areas; lagoons should never be located in sinkholes or in drainage fields near sinkholes.

Septic Tanks. Soil-cover thickness and type is of primary importance. In too many cases septic tanks have been located on or in the bedrock, where no filtration could take place, and either surface or groundwater pollution occurred.

Sewage Treatment Plants. Few problems are anticipated with sewage treatment plants in this area since bedrock and soil are favorable to their construction. However, plants should be located so that effluent is discharged into a perennially flowing stream. In the case of losing streams, discharge could enter the groundwater system.

Sanitary Landfills. Sites are generally difficult to locate because of thin soil cover. Where adequate soil cover is present, especially in the western portion of this unit, small community landfills can be located with less danger of contamination of the groundwater supply. It is recommended that a complete geologic investigation be made at several prospective sites to determine the best one. In areas where karst is well developed, sanitary landfills should be discouraged except under extreme conditions and, in all cases, a thorough geologic investigation should be made.

Impoundments. Lakes can be developed in most parts of this area. Soil depths are adequate in the western and southern parts of the area. If bedrock is encountered while excavating at a lake site, undercutting and repacking with impermeable clays are necessary to prevent leakage. Lakes developed in karst areas can trigger collapse and are more likely to fail than those built over competent bedrock.

Construction. Only areas within the karst region are unfavorable for the construction of large buildings.

Unit Nine - Shallow Residual Soil Over Sandstone Bedrock (Ss-I)

This unit is in central Franklin and southern Jefferson Counties. Bedrock consists of massive sandstone. The soil cover is from 0 to 30 feet thick and consists of red, sandy clay mixed with sandstone boulders and cobbles. Permeabilities of both soil and bedrock are high.

Sewage Lagoons. Sites suitable for sewage lagoons will be difficult to locate. Remedial measures such as impermeable clay padding will be necessary to insure that the lagoon will not leak effluent into the sandstone bedrock. If bedrock is encountered during excavation, it will be necessary to overexcavate and seal with packed clay.

Septic Tanks. Septic tanks should be used sparingly, and only in those areas where there is deep soil cover. Septic tank density should not be greater than one tank on every three acres.. Areas with thin soil cover or high septic-tank density will have groundwater-pollution problems.

Sewage Treatment Plants. There are no suitable areas for treatment plants within this unit. Any effluent discharged would soon permeate the soil or exposed bedrock and cause pollution problems.

Sanitary Landfills. Sites suitable for development as sanitary landfills are difficult to locate. Remedial measures, necessary in each case, will vary with the size of the landfill and the available soil cover.

Impoundments. Suitable sites are very difficult to locate. High permeability of the rocks and soils make water retention in a pond or lake difficult.

Construction. Problems include occasional sinkhole collapse and moderate to severe hillslope erosion.

Unit Ten - Alluvial Soil (Al-Tu)

This unit comprises the alluvial floodplains of the Missouri and Mississippi Rivers and, to some extent, portions of the floodplains of the Meramec, Bourbeuse and Big Rivers. Soils are composed of an admixture of gravel, sand, silt and clay with thicknesses ranging from 5 to 40 feet.

Sewage Lagoons. Sewage lagoons can be utilized, but provisions must be made to prevent the lagoon site from being flooded or ruptured. Depth of excavation should be limited to from 3 to 5 feet.

Septic Tanks. The use of septic tanks is not recommended since groundwater is an important resource in this area.

Sewage Treatment Plants. Sewage-treatment plants can safely discharge effluent into the rivers in this area.

Sanitary Landfills. The same limitations placed on septic tanks apply to landfills.

Impoundments. Few problems are anticipated for small ponds in the river valleys. Flooding poses the greatest problem.

Construction. The major problem will be occasional flooding.

* * * For additional geologic information concerning this area see the selected references: 2, 3, 6, 7, 8, 9, 13, 14, 15, 16, 17, 18, 20, 21.

VERNON COUNTY, KAYSINGER BASIN REGION

Summary

The topography of Vernon County is relatively flat. Gently rolling hills prevail, and relief seldom exceeds 90 feet.

The bedrock formations include cyclical sequences of limestone, shale, sandstone and coal. These units are generally flat-lying. Vernon County is not considered to be in danger of earthquake activity.

Mineral resources currently produced in Vernon County are stone and oil. Coal, clay and shale were mined in the past. Sand and gravel are produced intermittently from stream deposits.

Water resources are adequate. However, with increased growth in Vernon County several factors will affect the county's water needs. These factors are low-flow of the area's streams and salt water (or mineralization) encroachment of groundwater supplies. Additional water could be obtained by using surface impoundments.

Proper land use (waste disposal and construction) will require careful geologic investigation. Locations suitable for development as waste-disposal sites can be chosen without great difficulty. However, some remedial measures may be necessary to insure success and prevent water pollution.

Problems similar to those encountered in Vernon County with regard to waste-disposal, mineral resources and water resources will confront the developer in the surrounding four counties.

This report is not intended to furnish all of the geologic information needed for proper land development. It is intended to serve as a regional appraisal of the geologic features, resources and problems of Vernon County and can not take the place of on-site geologic investigation of proposed development sites.

Landforms and Relief

The topography of Vernon County is dominated by gently rolling plains. Relief is commonly between 50 and 90 feet. The floodplains of the county's major streams, the Marmaton and Little Osage Rivers, are narrow and seldom are wider than ½ mile.

Rock and Soil Formations

Bedrock consists of alternating beds of limestone, shale, coal and sandstone. Soil cover is predominantly an impermeable silty-clay and although it is thin (10 feet) in the south it becomes thicker (30 feet) in the north.

Earthquake Potential

Bedrock units in Vernon County are for the most part flat-lying. Only in those areas where faulting and folding have occurred is there any deviation from this. One structure, the Swarts-Garland dome, serves as a gas trap. Vernon County is not considered to be in danger of earthquakes.

Scenic Natural Features

There are no caves or "big" springs in Vernon County. Eldorado Spring, in neighboring Cedar County, has a daily discharge of 6,500 gallons and is the nearest significant spring. Many small springs of lesser importance are common in the area.

Mineral Resources

Vernon County is rich in mineral deposits. Coal, clay and shale, sand and gravel, stone, asphaltic sandstone and oil and gas are present in amounts of varying importance.

Coal. Vernon County has produced over 9 million tons of coal in the past and possesses a remaining reserve of more than 600 million tons, more than 400 million tons of which are strippable.

The Mineral coal seam was formerly mined extensively near Arthur, in northern Vernon County. This bed is one of the thickest coal deposits in western Missouri. However, most of the better deposits have been mined out.

The Mineral and Croweburg coal beds are present just beneath the surface under large areas of western Vernon County, where they have been stripped on a small scale in numerous localities. Although thin, both beds are persistent and offer some possibilities as strip coal, especially near Bronaugh, Deerfield and Stotesbury. Potentially strippable coal deposits are also present near Walker. One or two thin coal seams, notably the Rowe and Drywood, occur in the vicinity of Nevada and have been mined on a small scale. The potential for mine development in these seams is not great in the Nevada area.

Clay and Shale. Considerable clay and shale are present in the Pennsylvanian rocks which underlie Vernon County. In the past, minor amounts of brick and tile were manufactured. In addition to brick and tile manufacture, some units may be suitable for the manufacture of lightweight aggregate.

Sand and Gravel. Only minor amounts of sand and gravel have been produced in Vernon County. A detailed geologic examination of the region is required if potential sand and gravel resources are to be located and evaluated.

Stone. Crushed stone is produced in Vernon County from the Higginsville Limestone. Principal uses are for concrete aggregate, road metal and agricultural limestone.

Asphaltic sandstone, produced in eastern Vernon County near Sheldon, is used for paving material.

Oil. Minor amounts of oil are presently produced in Vernon County. Future production is expected to fluctuate with changing economic conditions, with no great amount of production anticipated. However, Vernon County possesses large resources of asphaltic sandstone containing low-gravity oil. The high viscosity of this oil makes its production impossible under current economic conditions. The development of this resource will depend upon the development of a more satisfactory method of recovery than is currently available.

Water Resources

Surface Water. The Marmaton and Little Osage Rivers and their tributaries drain Vernon County. Very little groundwater comes out of storage to maintain the flow of these streams, and as a result the streams have poor low-flow characteristics during periods of little rainfall. Small surface impoundments on the major streams could serve as a source of water for smaller communities.

Groundwater. The bedrock aquifers in Vernon County consist of sandstone, limestone and shale. Most domestic wells range in depth from 125 to 500 feet, although many are less than 200 feet deep. Yields from these wells range from 5 to 50 gallons per minute. Public wells in the Nevada area penetrate into deeper sandstone and dolomite aquifers. Because of rather constant water withdrawal from these aquifers, water quality has decreased as mineralized waters have been drawn into the county's water fields. Public wells range from 550 to 650 feet in depth. Yields commonly vary from 50 to 300 gallons per minute. Quality of this water is usually good, except for that which comes from aquifers that have been subjected to saltwater encroachment. Because of the variable quality of the county's water supply, usage of this resource is limited.

Unit One - Cyclic Sedimentary Bedrock (Cy)

Unit one is in all but extreme northeastern Vernon County and the valleys of the major streams. Bedrock units consist of alternating shale and limestone with some coal and sandstone layers. Soils are developed on the bedrock surface and vary from a silty clay to sandy clay. Thicknesses are generally less than 10 feet.

Sewage Lagoons. The general water tightness of the soil and bedrock effectively reduces pollution, making lagoon construction feasible where other conditions are favorable. If sandstones are exposed during excavation, routine remedial procedures of undercutting and padding are necessary and can be done without excessive costs.

Septic Tanks. Tanks should not be used in densely populated areas. Discharge from tanks does not permeate the host rock in the area well enough to be adequately dispersed and can result in water standing around foundations and possible ponding in low areas and ditches. In general, a 3-acre seepage field should be allotted for each septic tank to insure proper dispersal of pollutants.

Sewage Treatment Plants. Sites suitable for receiving discharged effluent can be located with little difficulty. In most cases there is little loss of stream water to bedrock and, because of this, the area's streams are ideal for receiving treated effluent. Careful investigation is needed to determine the suitability of each proposed site for this type of waste disposal.

Sanitary Landfills. If correctly located and properly operated, a landfill will cause minimal pollution. Ideal locations can be found in the smaller creek valleys, but diversion ditches are needed to prevent flooding of the landfill site and subsequent stream pollution.

Impoundments. Lake development is most favorable in this plains area, with minimal seepage problems occurring where there are underlying clayey or shaly soils. Sandstone regions pose a greater hazard because of probable seepage through fractures. Leakage is also possible along coal seams and limestone layers. These problems can be overcome by core trenching to unweathered bedrock, careful borrow-site selections and occasional soil blanketing. Severe problems might be encountered where there are numerous sandstone exposures.

Construction. The most significant problem associated with construction in Vernon County is the expansion of the clayey soils. Proper drains and deeply seated foundations can overcome this problem, however.

Unit Two - Carbonate Bedrock With Some Shale (Ca-Sh)

This unit is in the extreme northeastern part of Vernon County. Bedrock consists of massive limestone and some shale. The soil overlying bedrock is primarily a silty clay and is generally less than 30 feet thick.

Sewage Lagoons. Sites suitable for development as sewage lagoons still require some remedial measures if success is to be insured. Lining the lagoon with a bentonite-and-clay mixture is often sufficient to prevent leakage.

Septic Tanks. The use of septic tanks should be restricted to rural or farm areas because of the moderate permeability of the soil. Heavily populated areas would probably have surface pollution because of over saturation.

Sewage Treatment Plants. Careful consideration and geologic examination are necessary before choosing discharge points for treated effluent. The streams in this area are gaining, however, so there is little chance of subsequent groundwater pollution caused by water leaking from the receiving streams.

Sanitary Landfills. There are many suitable sites for development of landfills in this unit. Remedial measures may be needed, however, such as using a bentonite-and-clay-mixture padding to prevent leaking of leachates into the area's streams. Suitable material for daily and final cover is generally available at most sites or nearby.

Impoundments. Sites suitable for farm ponds and small lakes are easily found. However, some remedial measures may be necessary to prevent too much leakage.

Construction. Problems encountered include poor slope stability where there are thick shales and variable strength of bedrock.

Unit Three - Alluvial Soil (Al)

This unit occupies the alluvial valleys of the county's major streams, the Marmaton and Little Osage Rivers. These valleys, deep and narrow in western Vernon County, are wider and flat in the east. Soil thicknesses vary from 0 to 40 feet. The soil is an admixture of sand, silt, clay and gravel.

Sewage Lagoons. The construction of a lagoon in this unit may lead to flooding of upstream developments, as well as pollution of downstream waters. Therefore, great care should be taken in selecting a lagoon site.

Septic Tanks. Septic tanks can be used in this unit with caution. Water supplies are easily contaminated by improperly filtered septic-tank effluent. Septic tanks can be used only in rural areas where a minimum 3-acre field is available for filtration.

Sewage Treatment Plants. Treatment plants can be utilized if discharge is limited to gaining streams.

Sanitary Landfills. Favorable sites are those where there is a thick, clay-rich soil which can prevent leachates from leaking into the groundwater. Areas away from the stream are best.

Impoundments. Lakes can be constructed with some difficulty. The dam site will have to be overexcavated at the base and sides to insure that no leakage will take place around the dam. If permeable bedrock is encountered, the project may not be feasible because of increased costs.

Construction. Problems most often encountered include flooding, seepage and varying soil strength.

* * * For additional geologic information concerning Vernon County see these selected references: 2, 3, 6, 7, 8, 13, 14, 15, 16, 17, 18, 20, 21.

CEDAR, HENRY, HICKORY AND ST. CLAIR COUNTIES-
KAYSINGER BASIN REGION

(Limited to the general boundaries of Sensitive Area #18)

Summary

The topography of this four-county area is diverse. Both gently rolling hills and a highly dissected plateau are present. Relief is seldom greater than 150 feet and usually only 100 feet.

The bedrock units consist primarily of limestone, dolomite and shale, with some coal. Overlying bedrock is a thin deposit of wind-blown silt. These bedrock and silt units, in turn, have been weathered to form a soil. This soil cover is thin to moderately thick, and is primarily a silty clay, but may be a clayey silt or stoney clay.

This four-county region is not considered to be in danger of earthquake activity.

Present mineral production is limited to crushed stone. Other mineral resources include lead, zinc, barite and coal. All have been mined in the past. Also present are large deposits of clay and shale suitable for the manufacture of structural clay products.

Water resources are plentiful, but increased demand for potable water may require increased use of surface water. Groundwater resources are plentiful. However, mineralization increases east to west in Henry and St. Clair Counties, and therefore much of the groundwater available in the western portions of these counties is unpotable. Increased pumping from wells in the eastern portions of these counties may induce encroachment of mineralized waters into the area from the west.

Land-use (construction and waste disposal) will require careful geologic investigation at each proposed development site. Sites suitable for use in waste-disposal projects can be located with moderate difficulty. Soil and bedrock permeability will be an important factor in choosing where to construct a sewage lagoon, septic tank, or sanitary landfill.

Problems encountered in this four-county area dealing with resources and waste disposal will also be encountered in the counties immediately adjacent to the region.

This report is intended to serve as a regional appraisal of the geologic features, resources and problems of Sensitive Area 18. It is not intended to furnish all the geologic answers needed for successful site development. Careful on-site geologic investigation is recommended in all cases to insure proper regional planning.

Landforms and Relief

The topography of this four-county area is varied. In the north and west, gently rolling hills prevail. Relief in this area seldom exceeds 100 feet. In the south and east a highly dissected plateau is dominant. Here, relief is greater and generally varies from 100 to 150 feet. The floodplain of the area's principal stream, the Osage River, is narrow and generally is no more than 1/8-mile wide. The floodplains of its tributaries, however, are much wider and in the case of Sac and South Grand Rivers vary from 1/2- to 2/3-mile wide.

Rock and Soil Formations

The bedrock units consist of thick cherty dolomite, limestone, cherty limestone, shale, and coal. Overlying bedrock is a thin (2 feet to 5 feet) deposit of wind-blown silt (loess). Soil cover has developed over bedrock and loess. Thicknesses vary with location, but in general are less than 40 feet. Alluvial soil deposits vary in thickness from 10 to 40 feet.

Earthquake Potential

Bedrock formations in this four-county area are, for the most part, flat-lying. However, there are exceptions to this, expecially where faulting or folding have occurred. Several faults and folds have been mapped in the southern part of St. Clair County and the northern part of Cedar County. Dips in this area are generally steeper than elsewhere in the four-county area. The four-county area is not considered to be in danger of earthquake activity.

Scenic Natural Resources

Thirty-four caves are reported from the Cedar, Henry, Hickory and St. Clair Counties area. Cow Bridge Cave, in Henry County, is the only reported natural bridge in the area.

Many small springs are found in this area. Eldorado Spring, near Eldorado Springs in Cedar County, has a discharge of 6,500 gallons per day.

Mineral Resources

Mineral resources found in this area include lead, zinc, barite, clay, shale, stone and coal. Stone is the only mineral commodity being produced at present.

Lead-Zinc. Lead and zinc were produced in Hickory County from mineralized filled-sink structures prior to 1910. Deposits were generally small and quickly mined-out. Future production from this type deposit is considered unlikely. The potential for deep mineralization is unknown.

Barite. Barite formerly was produced from circle deposits in Hickory County. These barite deposits were often associated with lead and zinc mineralization. The deposits were quite small, and any future production will be minor.

Clay and Shale. Much clay and shale is present in Henry and St. Clair Counties. Although the material is suitable for the manufacture of structural clay products, there is no present production.

Stone. Limestone is quarried at several locations in Cedar, Henry and St. Clair Counties. The crushed stone is used for concrete aggregate, road metal, aglime and rip-rap. Reserves of limestone are unlimited.

Coal. About 1 billion tons of coal reserves are present in southern Henry County and northwestern St. Clair County. A large amount of this coal is strippable.

Water Resources

Surface Water. The principal streams draining the area include the Osage and Sac Rivers (draining St. Clair and Cedar Counties) and the South Grand River (draining Henry County). Because of the nature of the bedrock underlying this county, runoff after storms is rapid and low-flow characteristics are poor. Many of the smaller streams dry up completely, with almost no water coming out of groundwater storage to maintain flow. The Sac and Osage Rivers, however, have fairly large drainage basins above the point where they flow out of St. Clair County, and their low-flow characteristics are fairly good. For this reason they must be considered as an important resource, both as a source of domestic and municipal water, and as a source of diluting water for municipal sewage.

It is possible that small impoundments on carefully selected tributaries could be used for supplemental sources of water within the four-county region.

Groundwater. The four-county area is directly underlain by sandstones, shales, and limestones, which have widely varying hydrologic characteristics. Beneath these rocks lie the dolomite and sandstone units. Because of this complexity of rock type and the complex hydrology, domestic wells in the county have widely varying depths and yields. Many of the domestic wells drilled in St. Clair County are less than 200 feet deep, and a great many of these are less than 150 feet deep. Shallow domestic wells in Cedar, Henry and Hickory Counties are generally deeper and range from 200 to 450 feet. Yields of these domestic wells range from 3 to 30 gallons per minute in Henry County and from 5 to 50 gallons per minute in St. Clair County. Yields of domestic wells in Cedar and Hickory Counties fall within this range. Water quality in the shallower aquifers is usually good, with the exception of local wells in the western part of the area. If proper well-construction practices are adhered to, then no problem of contamination will occur.

Public-water-supply wells drilled in this region generally penetrate deeper aquifers. Wells drilled in eastern St. Clair County range from 550 to 650 feet deep and have yields of 50 to 300 gallons per minute. Casing is required to exclude pollutants. Casing depths average 250 feet. Public-water-supply wells drilled in eastern Henry, Cedar, and Hickory Counties are generally deeper and range from 450 to 1,200 feet. Yields vary from 12 to 500 gallons per minute. Water quality is variable. Deeper wells drilled in western Henry and St. Clair Counties yield water that is quite mineralized and usually unpotable. Deeper wells in eastern Henry and St. Clair Counties and those in Cedar and Hickory Counties yield good-quality water. In general, dissolved constituents become more concentrated from east to west.

Because of the groundwater-quality limitations imposed on the deeper aquifers, increase in usage of this resource in St. Clair and Henry Counties is also severely limited. Increased pumpage of wells drilled into deeper aquifers would undoubtedly cause encroachment of the more mineralized waters. In Cedar and Hickory Counties, however, there is no problem with highly mineralized waters, and because there is little demand for groundwater, a three-fold increase could be tolerated without seriously depleting the resource.

Land Use

Proper land use in this four-county area will require careful geologic investigation at each proposed site. Five engineering-geologic units are present in the area. These units conform to those designated by Hoffman in Stout and Hoffman (1973).

Unit One - Cyclic Sedimentary Bedrock (Cy)

Unit one is in central and western St. Clair County, southern Henry County, and northern Cedar County. The bedrock units consist of alternating shale and limestone, with some coal and sandstone layers. Soils are developed on the bedrock surface and vary from a silty clay to sandy clay. Thicknesses are generally less than 10 feet.

Sewage Lagoons. The general watertightness of the soil and bedrock effectively reduces pollution, making lagoon construction feasible when other conditions are favorable. If sandstones are exposed during excavation, routine remedial procedures of undercutting and padding will be necessary and can be done without excessive costs.

Septic Tanks. These should not be used in densely populated areas. The discharge from these tanks does not permeate the host rock well enough to be adequately dispersed and can result in water standing around foundations and possibly ponding in low areas and ditches. In general, a three-acre seepage field should be allotted for each septic tank to assure proper dispersal of pollutants.

Sewage Treatment Plants. Sites suitable for receiving discharged effluent can be located with little difficulty. In most cases there is little loss of stream water to bedrock, and because of this, the area's streams are ideal receivers of treated effluent. Careful investigation will be necessary to determine the suitability of each proposed site for this type of waste disposal.

Sanitary Landfills. Pollution from a correctly located and properly operated landfill will be minimal. Ideal locations can be found in the smaller creek valleys. However, diversion ditches will be necessary to prevent flooding of the landfill site and subsequent stream pollution.

Impoundments. Lake development is most favorable in this plains area, with seepage problems being minimal where there are underlying clayey or shaly soils. Sandstone regions pose a greater hazard because of probable seepage through fractures. Leakage is also possible along coal seams and limestone layers. These problems can be overcome by core trenching to unweathered bedrock, careful borrow-site selections and occasional soil blanketing. Severe problems might be encountered where many sandstone exposures are present.

Construction. Significant problems associated with construction include expansion of the clayey soils. Proper drains and deeply seated foundations will overcome this problem.

Unit Two - Variable-Thickness Soil Over Carbonate Bedrock (Ca-V)

This unit is located in northern Cedar County. The bedrock consists of permeable limestone which has weathered to produce karst. Soil cover has developed over the bedrock and is generally a red, stony clay soil. Both bedrock and soil are highly permeable, with much surface water being lost by seepage. Soil thicknesses vary from 0 to 40 feet.

Sewage Lagoons. Waste disposal by lagoons is hazardous because of seepage problems, particularly into caves and solution channels. Sewage lagoons built above voids such as caves may also collapse into the caves and contaminate the groundwater.

Septic Tanks. Disposal by septic tanks poses similar problems. The discharge, if not filtered or retained, but allowed to enter shallow groundwater supplies, may cause pollution and eventual loss of water for home and farm uses. Sinkholes or caves are not to be used for waste disposal of any type. The numerous caves and their subsurface streams transmit contaminants as readily as do surface streams.

Sewage Treatment Plants. Discharge of treated effluent should be made only into gaining streams. Careful investigation will be necessary to insure that effluent does not enter the groundwater system through sinkholes that may be present in the area.

Sanitary Landfills. Landfill sites must be carefully selected because of potential seepage problems. Soil thickness, in many cases, will be insufficient, and leachates may leak directly into bedrock and cause pollution of the area's groundwater resources.

Impoundments. There are few areas within this unit that are suitable for lake development. Vertical loss of water, both in the watershed and lake area and poor foundation conditions at the dam site contribute to the failure of many lakes. One of the few suitable areas is in the upland-soil region, where small lakes are feasible if necessary precautions are taken, including the careful selection of borrow sites. There are some potential sites for large lakes along major streams where there is perennial flow.

. The most unsuitable areas for lake sites lie on the slopes between upland prairies and the major streams. The groundwater table in these areas is relatively low, the fine-textured soils have been removed by surface erosion, and suitable foundations for dam sites have been destroyed by weathering.

Construction. Generally the overburden and bedrock will support building construction if normal precautions are taken. However, there are two unusual features which have a great effect on roads and construction. The first is that the red, clayey soils are hard to compact and, second, the underlying limestone is irregularly pinnacled, so depths to bedrock fluctuate severely. Careful subsurface exploration is necessary for foundations of larger structures.

Unit Three - Intermediate-Thickness Residual Soil Over Carbonate Bedrock (Ca-I)

This unit is located in western Hickory County, eastern and southern St. Clair County, and northern Cedar County. Bedrock formations consist of permeable carbonates. Covering this is a stony, red clay soil. Soil thickness varies from 20 to 40 feet, and permeability varies from low to high.

Sewage Lagoons. Sites suitable for development as sewage lagoons will be difficult to locate. Because of the varying permeability and thickness of the soil cover, it will be necessary that each proposed site be carefully investigated by a geologist. Lagoons constructed in areas where thin soil or soils of high permeability are found are likely to fail if remedial measures are not taken. Leakage can be lessened by the use of impermeable clay padding or bentonite.

Septic Tanks. Because of the nature of the soil, septic tanks should be used only where the soils have moderate permeability. This will allow for proper filtration of the effluent. Septic tanks should be used only in rural settings where there will be three or more acres per tank serving as a drainage field.

Sewage Treatment Plants. Treatment-plant discharge should be made only into streams with perennial flow. The permeable nature of bedrock and soil is conducive to pollution of groundwater supplies.

Sanitary Landfills. Suitable sites will be difficult to locate. Only those areas where impermeable, thick, clay soils are present are acceptable. In some cases, the clay soil may have to be treated with bentonite or padded with impermeable clay to prevent leakage.

Impoundments. Small farm ponds may be constructed with some difficulty. Bentonite or clay padding may be necessary to prevent leakage. Large impoundments will be difficult to construct because of the permeable nature of the bedrock and soil.

Construction. Problems encountered include low-wet-soil strength and variable permeability of the soil.

Unit Four - Carbonate Bedrock With Some Shale (Ca-Sh)

This unit is in western Hickory County, northern Cedar County, and portions of St. Clair County. Bedrock is composed primarily of limestone and shale. Soil is a clayey silt. Thickness of the soil is less than 30 feet.

Sewage Lagoons. Satisfactory sites for sewage lagoons can be located with relative ease in this area, except where the terrain is more rugged and where soil is thin. Most problems can be overcome by choosing a proper site and using engineering-design techniques. For example, perhaps only a portion of a lagoon site will be suitable, but with the addition of clay or bentonite, seepage loss can be prevented. Because conditions at each proposed lagoon site will vary, an investigation should be made to determine the capabilities of each site.

Septic Tanks. Due to the varied nature of the bedrock (carbonates and shales), a detailed study is necessary for each proposed site. The success of a given septic tank will depend upon the characteristics and depth of the soils present and the density of septic-tank development. Areas that have shallow soils are poorly suited for septic tanks, except perhaps for rural areas such as farms or large estates. The remaining part of unit one has sufficient soil cover to permit septic tanks to be used in lightly urbanized areas where lot sizes exceed three acres.

Sewage Treatment Plants. Sewage Treatment plants can be located without much difficulty relative to geologic conditions of the receiving stream. All treatment plants should be located so that discharged effluent will enter gaining streams, which are common in this unit.

Sanitary Landfills. Sites that are acceptable for landfills are for the most part limited to areas of thick soil cover. Soils in the four-county area are well-suited for sanitary landfills, but extreme caution should be used when selecting a site.

Impoundments. Most areas are suitable for lake development. Areas where carbonates and sandstones crop out may have some seepage problems, but padding with clays may help prevent leakage.

Construction. No serious problems are anticipated in finding sites where small buildings such as houses can be built. Careful examination should be made of the bedrock and soil, however, when buildings larger than homes are to be constructed and for any buildings to be erected on a steep slope.

Unit Five - Alluvial Soil (Al)

This unit is not shown on Hoffman's map because of the unit's small size. The unit occupies the alluvial valleys of the Sac, South Grand, and Osage Rivers. Alluvial soils may also be present in the valleys of the larger tributary streams. Alluvial soil thicknesses vary from 0 to 40 feet. The soil is an admixture of gravel, sand, silt and clay.

Sewage Lagoons. The construction of a lagoon in this unit may lead to flooding of upstream developments, as well as pollution of downstream waters. Therefore, great care should be taken in selecting a lagoon site.

Septic Tanks. Septic tanks can be used in this unit with caution. Groundwater supplies are easily contaminated by improperly filtered septic-tank effluent. Septic tanks could be used in rural areas where a minimum three-acre field is available for filtration.

Sewage Treatment Plants. Treatment plants can be utilized if discharge is limited to gaining streams.

Sanitary Landfills. Favorable sites are those where there is a thick, clay-rich soil which can prevent leachates from leaking into the groundwater. Areas away from the stream are best.

Impoundments. Lakes can be constructed with some difficulty. The dam site will have to be overexcavated at the base and sides to insure that no leakage will take place around the dam. If permeable bedrock is encountered, the project may not be feasible because of increased costs.

Construction. Problems most often encountered include flooding, seepage, and varying soil strength.

* * * For additional geologic information concerning the Cedar, Henry, Hickory and St. Clair Counties area see these selected references: 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 20, 21.

BENTON - CAMDEN - MILLER - MORGAN COUNTIES

(Limited to the General Boundaries
of Sensitive Area #16 - The Lake of the Ozarks)

Summary

The Lake of the Ozarks lies within a region of rugged topography. The land has been dissected by streams to form deep valleys and steep, elongated and sometimes ridge-like hills. Relief ranges from 100 to 200 feet. Floodplains of the major streams vary from one-third to one mile wide.

Bedrock formations consist of limestone, cherty limestone, dolomite and sandstone. The carbonate formations are thick-bedded, and in many places there are karst features such as solution channels, sinkholes and caves. Both carbonates and sandstones have been deeply weathered to form sandy, cherty, clay soils. These soils vary from 0 to 75 feet deep.

The area is not considered to be in danger of earthquakes.

There are many scenic natural resources including caves and springs which are of interest to many people. Six caves are commercialized and offer guided tours to the public.

Mineral resources are not extensively developed. Barite is no longer mined on a large scale, although two barite mine-mills are intermittently producing in Benton County. These barite concentrates are shipped to Coffeyville, Kansas, where they are used for manufacturing paint. Lead, zinc and iron deposits are small and of such low grade that future production is unlikely. Stone is quarried for use as construction aggregate, aglime and rip-rap. Sand and gravel are produced for use as construction aggregates. Reserves of stone and gravel while not well distributed are adequate for the future.

Water resources are plentiful. Supplies of both groundwater and surface water are adequate. Well depths range from 175 feet to 1,200 feet, depending upon topography and the particular aquifer being tapped. Shallow wells yield up to 40 gallons per minute and the deeper wells yield up to 600 gallons per minute. Water quality is good and treatment is not usually necessary, but quality checks are needed to insure that only good water is used for human consumption. This area can tolerate large future increases in water demand if carefully managed.

Proper land use depends on rigorous geologic investigations being carried out at proposed development sites. Soil depths are sufficient in many parts of this region to insure satisfactory sites for waste disposal. Improper waste disposal sites must be avoided to guard against the pollution of the area's water resources. Impoundments can usually be constructed in areas where there are perennial flowing streams. Small farm ponds can be built wherever clay soils of sufficient thickness can be found, such as on hilltops and along margins of valleys.

Similar land conditions and problems are prevalent in the eleven counties surrounding this study area.

This report is not intended to provide all the information needed for geologically oriented development of this region. It is intended as a regional appraisal only and cannot take the place of actual on-site geologic investigation, which is recommended for any future land-development project.

Landforms and Relief

The Lake of the Ozarks region lies entirely within Benton, Camden, Miller and Morgan Counties. The westernmost part of this area, western Benton County, has a topography that varies from steep, elongated hills which have been dissected by streams to broad, flat floodplains. Floodplains along the major streams vary from one-third to one mile wide. Slopes of the hillsides range from 5 to 40 percent, and along the major streams they are sometimes nearly vertical. Relief in this area locally exceeds 160 feet along the Osage River, but it is generally no more than 100 feet elsewhere. In the remainder of the Lake of the Ozarks region, eastern Benton, Camden, Miller and Morgan Counties, the topography is very similar. Long, ridge-like, steep hills predominate. Floodplains of the major streams seldom exceed one-third mile in width. Relief is commonly in excess of 100 feet and along the major streams it reaches 200 feet.

Rock and Soil Formations

Bedrock formations in the Lake of the Ozarks area consist of limestone, cherty limestone, dolomite and sandstone. Carbonate bedrock is predominant. These carbonates are thick-bedded and have been deeply weathered. Karst features such as solution channels, sinkholes and caves are well developed. The carbonates and sandstones have weathered to form a moderate to thick soil overburden, mixed with chert, gravel and sandstone boulders over much of the area. This residual soil ranges in thickness from 20 to 40 feet in the westernmost part of the area. In the eastern portion of the area (eastern Benton County and Morgan, Miller and Camden Counties) soil thicknesses are greater and range from 40 to 75 feet. Soil thicknesses throughout the area are greatest on hilltops and in the valleys.

Earthquake Potential

For the most part the strata of the Lake of the Ozarks area are flat-lying. There is one major mapped fold, the Proctor Anticline, located in Morgan and Camden Counties. Bedrock in the immediate area of this fold dips away from the axis. Dips on the western flank are greater than those on the eastern flank: four degrees and one degree, respectively. In the south-central part of Camden County, the Red Arrow fault is present. Strata were displaced about 100 feet vertically. No earthquake activity is anticipated.

Scenic Natural Resources

Caves, springs, natural bridges and other places of geologic and scenic interest are found in the Lake of the Ozarks area. These are the result of the action of either ground water or surface water upon bedrock.

There are 149 reported caves in the area adjacent to the lake, seven of which are developed and commercially operated. These are: Bridal Cave, Ozark Caverns in Camden County; Arrow Point Cave, Indian Burial Cave and Enchanted (Stark) Caverns in Miller County; and Jacobs Cave in Morgan County. There are no commercial caves at present in Benton County.

Springs are quite common in the Lake of the Ozarks area. Eleven of these are of significant size and are considered "big springs". At all but one of these springs the average daily flow is in excess of 250,000 gallons per day. Hahatonka Spring in Camden County, the largest spring in the area, has an average discharge of 48 million gallons per day. Two of these springs, Wet Glaize and Gravois Mill Springs, supply water to fish hatcheries. These springs are private, but can be visited.

Natural bridges are present in this area, but their locations are usually not well known. One bridge is located in Camden County one quarter mile east of Hahatonka Spring and is easily accessible.

Mineral Resources

The Lake of the Ozarks region was at one time a very productive area within the Central District of Missouri. Mineral production has declined here, however, and today production is limited to crushed stone, and sand and gravel. There is some potential for barite.

Iron. Deposits of brown iron ore are generally small and low grade. The most recently reported iron-ore production was in 1957, in Miller County, when 720 tons were mined. Additional production is unlikely.

Barite. Barite was once mined, together with lead and zinc, in significant quantities. Deposits were found in residual clays, veins, solution channels, circles and filled-sink structures. Most of the deposits were small and shallow and quickly depleted. Production is currently limited to two small operations located near the Lake of the Ozarks, one south of Warsaw and the other east of Lincoln in Benton County. The barite concentrates are shipped to Coffeyville, Kansas, for use in the manufacture of paints by Sherwin-Williams Company. Future production will be governed by two factors: 1) the discovery of new barite deposits, and 2) higher prices for the barite concentrates. Lead and zinc ores associated with these deposits are insignificant, and prospects for development for lead and zinc metals are negligible. There is a slight chance of lead and zinc deposits being present in the Cambrian Bonneterre Formation.

Stone. Stone is quarried within the Lake of the Ozarks area for use as construction aggregate, road metal, aglime and rip-rap. Resources of stone suitable for low grade uses are present in all four counties and in unlimited amounts. Resources of stone suitable for high grade uses are restricted to northern Morgan and western Benton Counties and are quite limited.

Sand and Gravel. Numerous small and several large sand and gravel operations are active in the Lake of Ozarks region. Production for aggregate in readymix concrete, general construction and road surfacing. Present production is from inchannel deposits of the Osage River and major tributaries. Unlimited reserves are present as floodplain and inchannel deposits along the Osage River, however, they may not always be well located with respect to demand.

Water Resources

Surface Water. Surface water constitutes a major water resource in the Lake of the Ozarks area. Streams such as the Niangua, the Little Niangua, Pomme De Terre, Little Pomme De Terre, South Grand, Sac and Little Osage, and all their tributaries flow into the Osage River. This major stream is dammed to form the Lake of the Ozarks.

Runoff of precipitation overland and as groundwater discharge in this huge basin (14,000+ square miles) ranges from less than 8.0 inches in the western part of the area to approximately 10.0 inches in the eastern part. A large amount of this runoff is temporarily stored in the Lake of the Ozarks (2,000,000 acre-ft.).

Groundwater. Groundwater resources in the Lake of the Ozarks area are important for both domestic and public water users.

Rainfall averages between 35 inches and 41 inches per year with an estimated 25 percent appearing as streamflow and 75 percent being lost by evapotranspiration. How much of this comes from the groundwater reservoir and from water tied up in the soil or residuum is not known. Although groundwater storage may vary from year to year, the long term change in storage is negligible. The total amount of groundwater in storage is tremendous.

Generally the direction of groundwater movement is toward the northwest. However, this movement is locally modified by topography, changes in rock types, permeability and structural deformation of the rock units. Because this groundwater is under artesian pressure, each water-bearing horizon has its own pressure head. This is further complicated by the fact that there are connections between all of these water-bearing zones in the form of cracks, crevices and solution channels. Deeper aquifers are thus recharged by water from shallower aquifers.

Shallow Aquifers. All of the shallow rock units locally yield some water to wells. Some of these units consistently yield enough water to be considered dependable aquifers.

Shallow water-bearing units in the area include sandstone and dolomite that occur at varying depths, depending on topography (elevation), structure and geographic location of well site. Well depths range from 175 feet to 325 feet.

Yields of wells drilled into these horizons range from 5 gallons per minute to as much as 40 gallons per minute. Because of the open nature of the shallow bedrock units locally, it is possible that the higher-yield wells have fairly direct communication with surface water sources.

Deep Aquifers. The deeper aquifers yield water from rocks having similar hydrologic properties to the shallow aquifers. Yields are much higher, with a range of from 60 to as much as 600 gallons per minute. The units utilized include sandstone and dolomite of Ordovician and Cambrian age. The lowermost aquifer, the Potosi Dolomite, is the most prolific.

Most wells drilled into these aquifers to obtain large yields are public water-supply wells and are grouted in such a manner as to exclude all water-bearing zones above these major aquifers. Total depths of wells drilled into these units range between 550 feet to 1,200 feet, with casing depths of from 250 to 500 feet.

These aquifers must be protected from all sources of pollution. Improperly cased wells penetrating these units are possible avenues of pollution which would damage the usefulness of these aquifers for years to come.

Water quality from both the shallow and deep aquifers is excellent. It is exceedingly difficult to tell the difference between water from shallow sources and that from the deeper zones. Total dissolved solids in the water range from approximately 200 ppm (parts per million) to approximately 450 ppm, with the higher concentrations being in the deeper zones in the western part of the area. Chlorides, sulfates, nitrates and all other dissolved constituents are much lower than maximum permissible limits as set by the United States Public Health Service drinking-water standards.

Treatment of water from wells in the study area is usually not needed. Where proper casing depths and good well construction have been adhered to, there is very little danger of contamination of the groundwater supply. There are areas, however, where the shallower zones have been polluted locally by the works of man and by direct interchange of water with the lakes. Where this happens, it is necessary to set casing below the point where the contaminant is entering the well structure.

Groundwater reserves are plentiful and because of the relatively constant recharging of the aquifers the area could tolerate large future increases in groundwater withdrawal.

Land Use

Proper land use requires an understanding of all phases of geology, including bedrock and soil characteristics, structural features and water resources.

Two engineering bedrock-soil units are defined in this area. These units are those designated by Hoffman in Stout and Hoffman (1973) and shown on the Engineering Geology map.

Unit One - Intermediate-Thickness Residual Soil Over Sandstone Bedrock (Ss-I)

This unit is dominated by sandstone and dolomitic sandstone bedrock that has been weathered to form a moderately thin soil cover over most of the area. Soil depths usually range from 20 to 40 feet but may be thinner locally. Thickest soil cover is limited to hilltops, moderate slopes and valley bottoms. Steeply sloping hills and bluffs have very thin soil cover, usually 5 to 10 feet on the steep slopes and very little on the bluffs. Slopes vary from 5 to 40 percent in this area. This unit, which occupies a very irregularly shaped area, is located in eastern Benton, southern Morgan, western Miller and northern Camden Counties.

Sewage Lagoons. Because of the thin soil cover over most of the bedrock and the steep hillsides, construction of lagoons can be difficult, however, areas acceptable for sewage lagoon sites can be found. These are at the bases of hills and hill tops where adequate soil cover is present. Many of the small creek channels are suitable for lagoons if the stream flow can be diverted. An adequate thickness of clay should be present in the creek bottom to contribute to the building of the lagoon and to prevent leakage of the leachates into the soils. Lagoon sites that are cut into bedrock are unsuitable because they might leak horizontally and vertically into the bedrock along joints or fractures.

Septic Tanks. Because of the steep slopes and thin soil cover, septic tank effluent has little room in which to disperse and be filtered. The results of this are the subsequent surfacing of effluent and pollution of the immediate area. Ideal locations are on hilltops and at the bases of slopes where sufficient soil cover is present. If septic tanks are to be used in this area, they should be built only on farms or in other sparsely populated areas and not used in urbanized areas.

Sewage Treatment Plants. Suitable plant sites can be found along the larger streams in this unit. Discharge should be released only into those streams which have perennial flow. Smaller streams may be dry part of the year and are therefore unsuitable. Most waterways in this unit are gaining streams, although some loss can be expected where the bedrock is deeply weathered. Missouri Clean Water Commission regulations should be consulted before construction is begun and careful geologic examination is recommended to insure selection of the most favorable site.

Sanitary Landfills. Suitable sites are difficult to locate because of steep slopes and inadequate soil cover over most of the area. Where sufficient soil cover is present, such as on hilltops and in valleys, the amount of clay present is most important. This clay is needed to pad the floor of the landfill to impede the leakage of leachates and to serve as cover material. Exploration pits should be dug at each proposed site to determine the amount and type of soil present.

Impoundments. Sites that are adequate for the construction of large lakes are difficult to locate. Those areas best suited for lake development are valleys with perennially flowing streams. In many cases these streams will be lost where gravelly soils or fractured bedrock predominate and any lake built in these areas will fail; in some cases the stream will reappear or resume flowing some distance downstream from the point where it was lost. Areas downstream from the point of resumed flow usually are better-suited for lake sites. In many cases springs will contribute significantly to the flow of a stream and these springs are a good indication of areas acceptable for lake sites. Site investigation will be necessary to determine the extent to which the bedrock has been weathered and the amount of backcutting necessary in hillsides and valley floors for placement of the dam abutments and cut-off trench so that leakage does not occur around or beneath the dam site. Small farm ponds can be located much easier. Ideal sites are on hilltops and at the bases of hills where clays are thick enough to retain water.

Construction. No serious problems are anticipated. Construction should be limited to areas where karst features such as sinkholes are not developed. Site-selection investigation to determine the capabilities of the bedrock-soil system should be done in each case where buildings of significant size, such as multiple-family dwellings, barns and factories are built.

Unit Two - Intermediate-Thickness Residual Soil Over Carbonate Bedrock (Ca-I)

This unit is typified by its thick soil cover mixed with chert, gravel and sandstone boulders. Soil thicknesses vary from 20 to 40 feet but may be thinner locally. The bedrock consists of dolomite and sandstone which locally are highly weathered and permeable. The many losing streams present in this unit characterize the high permeability of the bedrock and soil. This area comprises those parts of Miller, Morgan and Camden Counties not included in unit one.

Sewage Lagoons. Lagoons can be safely built if proper precautions are taken. The best sites are those where soil cover is of sufficient thickness and land does not slope greatly. Precautionary measures to insure success include the use of impermeable clay padding where gravels or bedrock are encountered. In these cases, undercutting will be necessary to remove some of this permeable material. Lagoons cut deep into hillsides will most likely leak horizontally into the cut face. Those developed in creek valleys will need diversion channels and rip-rap; reinforced sinkholes should never be used.

Septic Tanks. The use of septic tanks is to be discouraged in all cases except where there is either little or no slope, soil thickness is 20 feet or greater and the land is sparsely settled. If these requirements are not met, serious problems will arise. Where steep slopes prevail, sewage effluent will travel downslope and may emerge on adjoining property and cause surface pollution. Where soil cover is not thick enough or less than three acres is available for each tank, the effluent will not be properly filtered and may surface and cause pollution problems. In areas where permeable bedrock is near the surface, unfiltered effluent may enter the groundwater system and pollute nearby springs. Use of septic tanks in dense-housing areas should be avoided, as the soil cannot absorb large amounts of liquid effluent.

Sewage Treatment Plants. Because of the very permeable soils and bedrocks, most streams in this area are losing. Effluent discharged into creeks will probably go underground at some point. Discharge should be limited to those streams with permanent flow.

Sanitary Landfills. Satisfactory landfill sites can be located without too much difficulty. Areas suited for development are valleys, gently sloping hillsides and some hilltops. Sites developed in the valleys should be protected from flooding creek waters and should also include a small impoundment to trap leachates that might otherwise enter the stream directly. All proposed landfill sites should be investigated to determine the types and amounts of soils present. Sinkholes should not be used.

Impoundments. Requirements pertaining to the building of successful lakes and ponds in unit one also pertain to this unit.

Construction. No problems are anticipated for small buildings such as homes. Investigation should be carried out before any larger buildings are constructed.

* * * For additional geologic information concerning the Lake of the Ozarks area see these selected references: 2, 3, 6, 7, 8, 13, 14, 15, 16, 18, 20, 21.

PULASKI COUNTY, LAKE OF THE OZARKS REGION

Summary

Pulaski County lies in central Missouri. High relief prevails. Many streams and rivers have dissected this area and left behind long, narrow divides with steep slopes. Floodplains are commonly broad and are frequently flooded with springtime runoff. Dolomite bedrock is exposed on some steep slopes and along river bluffs. Soil cover is quite thick with depths commonly ranging between 20 feet in the northern part of the county to 100 feet in the southern part.

Mineral resources are limited. Stone is quarried for use as construction aggregate, aglime, and road-surfacing material. Sand and gravel is produced from the Big Piney River floodplain for aggregate in readymix concrete, construction aggregate and road surfacing. Resources of material suitable for construction uses are plentiful, although not well distributed.

Water resources are plentiful. Surface water is currently used only by Fort Leonard Wood. Groundwater supplies are adequate, and future needs for a growing Pulaski County can be met. Problems in obtaining groundwater of good quality are usually caused by failure to properly case wells. Casing must extend through clay-filled fissures in the dolomite bedrock.

Successful land use can be achieved in Pulaski County by proper geologic investigation of proposed sites prior to development. Sewage lagoons, septic tanks, and lakes can usually be constructed where the land is flat or there are gently dipping slopes. Sinkhole areas should be avoided to prevent alteration of the local drainage pattern, which could cause subsequent collapse of soil or bedrock and possible groundwater pollution. Sanitary landfills are possible in areas with gently sloping surfaces. Adequate soil cover is necessary for blanketing the landfill after each deposit has been compacted. Leachates leaking from landfills should be trapped in small impoundments where they can be held until oxidized. Sewage-treatment plants should be built only in those areas where it will be possible to discharge treated effluent into permanently flowing streams. Construction of large buildings should be limited to relatively karst-free areas to avoid possible catastrophic

bedrock collapse. Larger buildings should not interfere with normal drainage unless measures have to be taken to safely divert this flow to prevent soil collapse.

Similar geologic problems are encountered in the adjacent areas of the six surrounding counties.

This report is not intended to provide all the information required for geologically oriented development. It is intended to serve only as a regional appraisal of the geologic features, resources, and problems of Pulaski County and cannot take the place of actual on-site investigation, which is recommended for any future land development project.

Landforms and Relief

Pulaski County lies within the highly dissected plateau region of the Ozarks. The area is one of generally high relief and is dissected by many streams, including the Gasconade River and its tributaries, the Osage Fork, Big Piney River, and Roubidoux Creek. Commonly, relief is as much as 300 feet along the rivers. The floodplains of these rivers are usually quite broad and terraced. Width of these floodplains is generally one-third to one-half mile. Slopes in the Pulaski County region are quite steep, except on ridge tops and small plateau areas away from the rivers. There are numerous sinkholes through which precipitation can easily enter the groundwater system. Springs are numerous and contribute to the flow of the rivers.

Rock and Soil Formations

Bedrock in Pulaski County is almost entirely dolomite and sandstone. Some dolomite is chert-free, whereas others are very cherty. The chert-free dolomites are generally exposed along the deeper parts of the drainage basins. Cherty dolomite and sandstone comprise the valley walls, and chert-free, massive dolomites form the higher divides. Some sandstone is also present along the tops of the divides.

Residual material derived from the weathering of dolomite, cherty dolomite, and sandstone is quite variable in thickness and composition. Soil formed on hilltops is generally much thicker than that formed on hillsides. Soil depths range from 0 to 100 feet. Soil composition is generally red clay, with sand and chert interspersed, depending on the parent bedrock. The high plateaus are locally capped by a thin veneer of loess (wind-blown silt), generally 3 feet or less in thickness.

Earthquake Potential

Bedrock formations are gently folded and dip to the northwest. No major faulting has occurred and no major folds are present in the county.

The area is far removed from known seismic areas. Minor shocks have been felt in Pulaski County, as they have been everywhere in the Ozark region, but this is not a region with major earthquake problems.

Scenic Natural Resources

Many caves and springs are found in the Pulaski County area. Pulaski County leads all but one Missouri County in the number of caves reported, with 220. None of these caves are commercialized. One natural tunnel is located near Waynesville.

There are twelve major springs in Pulaski County as well as many others of lesser importance.

Mineral Resources

Stone, sand and gravel account for Pulaski County's entire mineral industry. Stone is quarried for construction aggregate, aglime, and road-surfacing materials. Stone suitable for these uses is present over large areas of the County. No reserves of high-quality stone are present. Dimension stone has been quarried in the past, although there is no production at present. Stone suitable for dimension blocks is present in the Roubidoux Formation (sandstone) and in the Jefferson City Dolomite (" Quarry Ledge" dolomite).

Sand and gravel are produced in Pulaski County for use in readymix concrete, general construction and road-surfacing. At present, operations are confined to the Big Piney River floodplain near Devils Elbow and Interstate Highway 44. Additional sand and gravel resources, although of questionable quality, are present along the Gasconade River. Smaller deposits are present along tributaries. Supplies are probably adequate for the near future unless restrictive legislation is passed.

Metallic mineral deposits include isolated occurrences of brown iron ore and pyrite. These filled-sink deposits are small and the ore grades are too erratic to have any future importance.

Water Resources

The water resources of Pulaski County are ample to meet all anticipated future needs.

Surface Water. The two major streams flowing within the county are the Gasconade and Big Piney Rivers. Only Fort Leonard Wood uses surface water which it obtains from the Big Piney River. The Big Piney is also used for recreational purposes and as a receiver of sewage effluent. Those chemical constituents that are usually considered objectionable are for the most part, nutrients which lead to excessive growth of algae and weeds. Judged in terms of the U. S. Public Health Service standards, the water of the Big Piney and Gasconade is of good quality. Low-flow characteristics of these streams are good since, during low-flow periods, flow is well supported by the many springs. The twelve larger springs in Pulaski County each discharge between 100,000 and 40,000,000 gpd. Total discharge is about 95,000,000 gpd.

Good quality groundwater can be obtained with properly constructed wells. As a result of rather deep weathering, formations tend to be open; there are many solution openings and caves. These openings form the flow channels of springs. A product of this weathering is residual red clay. Often this residual material occurs as fillings in rock fractures and crevices and if enough well casing is not used, this mud may enter the well, causing high turbidity and excessive iron content in the water. This very open system also permits the rapid movement of pollutants deep into the aquifers. With care, both the red clay and pollutants can be excluded from wells. However, as much as 500 feet of casing has not always been successful in excluding muds from some city wells. Private wells, which need much less water, often successfully avoid mud problems. With the smaller volume of water needed, an interval free of crevices with mud fillings can often be found to adequately supply private needs. Private wells commonly range in depth from 200 to 400 feet with casing sometimes required to be as deep as 200 feet. Yields range upward to 20 gallons per minute. Municipal wells have depths ranging up to 1,200 feet depending on the topographic setting. Most of these wells have yields of less than 200 gpm.

No adverse affects are to be noted on groundwater levels at present production rates. Any fluctuations that do occur are seasonal, coinciding with precipitation patterns. This, too, is indicative that recharge is ample to supply a large increase in water consumption. The readiness with which recharge occurs precludes the depletion of this water resource.

Aside from the effects of pollutants, there is a similarity in the chemical quality of the stream, spring, and groundwaters. Total dissolved solids average 300 parts per million; total hardness 250 ppm; and sodium and chlorides are low, averaging 2 and 3 ppm respectively. Sulfates are generally low, being about 15 ppm.

Land Use

Within Pulaski County there are six engineering bedrock-soil units. These units conform to those designated by Hoffman in Stout and Hoffman (1973). Any consideration of either bedrock or soil cover for development, whether it be for waste disposal, sanitary landfill, impoundment, or construction must necessarily involve the entire unit, not just a part of it.

Unit One - Intermediate-Thickness Residual Soil Over Carbonate Bedrock (Ca-I)

This unit is in the western part of the county. Bedrock consists mainly of dolomite with some dolomitic sandstone. Soils range between 0 to 40 feet deep, with the greater thicknesses on ridge tops and in valleys. Land use problems are not insurmountable if proper investigations are carried out to determine the individual limitations of each proposed site.

Sewage Lagoons. Steep hillsides and inadequate soil cover are the major problems encountered. Ideal lagoon sites are at the bases of hills and on ridge tops where soil cover is of sufficient depth. Impermeable clays may be necessary for padding of the lagoon floor. If, during excavation of the lagoon, sandstone or gravel beds are encountered, the lagoon floor should be overexcavated two feet and brought back to grade with a compacted clay pad. Grouting may be necessary if problems with fractured rock are anticipated. Leakage from a lagoon could permeate downward to enter and pollute the groundwater system.

Septic Tanks. Unless there is sufficient soil present for dispersal of septic tank effluent, the groundwater is likely to become polluted. Often, septic tanks have been built in areas where there is not enough soil cover, resulting in the pooling of effluent on the surface. If septic tanks are to be used, they should be restricted to sparsely populated areas such as farms.

Sewage Treatment Plants. In most of the area, streams with large watersheds flow year-round while smaller creeks may be dry during part of the year. Treatment plants should only discharge into perennially flowing streams, but this is not required if the effluent will remain on the surface long enough to be aerated. Some effluent loss may be expected in areas where the dolomite is highly weathered, or where caves and sinkholes are present. Careful investigation is required before such a plant is built.

Sanitary Landfills. Desirable sites for landfills are difficult to find. In most cases, thin soil is the limiting factor since soil is needed both as a padding for the landfill floor and as cover material. Suitable sites are locally present on hilltops and at the bases of hills. Depth to bedrock and amount of available soil cover should be determined prior to construction of a landfill.

Impoundments. The same limitations placed on sewage lagoons apply to small impoundments; the major problem is availability of adequate soil for dam construction. Some leakage can be expected in the lake basin by way of solution openings in the bedrock, but these are usually in spots and are not severe or widespread within an entire lake. Pressure grouting may be required to seal the lakes. Smaller lakes can be sealed with clay padding. Soil used for borrow material for a dam should not be taken from the lower part of a valley, because of the possibility of erosion. Areas below springs are often ideal for lakes because of the impermeable bedrock and water supply.

Construction. No serious geological limitations are placed on construction projects. Because developers should avoid areas where sinkholes and cavernous bedrock may affect the stability of multiple-story structures, careful geologic examination should be made before any large buildings are constructed. Though single-family homes are not as limited, they should not be built in sinkholes. Care must be taken to avoid changing the course of groundwater movement since this could cause collapse of either soil or bedrock.

Unit Two - Thick Residual Soil Over Carbonate Bedrock (Ca-T)

This unit is in southern Pulaski County. Massive dolomite bedrock covered with very thick, cherty clay soil (from 40 to 100 feet) is the dominant engineering-geologic unit present. Moderate to severe problems face developers in this area.

Sewage Lagoons. Lagoons can be constructed where there is sufficient soil thickness and the slope is not severe. If permeable gravels are encountered during excavation it is necessary to undercut an additional 2 feet and pad the site with impermeable clays.

Lagoons cut into hillsides can be expected to leak horizontally into the cut face. Lagoons built in small creek valleys will need diversion channels to prevent flooding and erosion of the site and pollution of downstream waters.

Septic Tanks. Septic tanks can be safely used in most areas where soils are of sufficient depth, at least 10 feet or more. Effluent will probably not surface and pool on the surface. In areas of dense housing, the soils will not be able to absorb the amount of effluent produced and septic tanks should not be used. The use of septic tanks on steep hillsides is not recommended either. Effluent discharged at a higher elevation on a slope will move downward and possibly resurface at a lower elevation.

Sewage Treatment Plants. Streamflow in this area is unpredictable because of the inconsistency in the permeability of both bedrock and soil. Any effluent discharged into the creeks will probably go underground at some point along its course. Discharge should be limited to streams flowing year-round.

Sanitary Landfills. Construction of landfill sites is possible within this unit. Careful geologic exploration should be made to determine the characteristics of the bedrock and soil. Adequate soil cover is present on most hilltops, gentle slopes, and valleys where thicknesses are from 10 to 20 feet or more. Losing streams are common in this area and, because of this, effluent landfill waters should be prevented from entering creek channels. The best method of preventing this is to build a retention lagoon a short distance downhill from the landfill to trap leachates.

Impoundments. Moderate to severe problems will be encountered in this unit. Water loss prevails throughout the entire valley region with loss usually taking place through cavernous bedrock, sinkholes, and highly permeable soils. Some soils in the valleys are subject to catastrophic collapse when saturated. Grouting is not necessarily successful because the whole valley is subject to water loss and soils native to the area are not suitable for padding material because of permeability. Locally, favorable sites can be found downstream from areas with springs. When leaks do occur within a lake, it is usually difficult to trace the water loss.

Construction. Major problems are not anticipated for single-family dwellings although care should be taken not to build in sinkholes where collapse is possible. Larger buildings must be built so they do not interfere with the natural flow of groundwaters which could cause soil saturation and subsequent collapse.

Unit Three - Karst (Ca-K)

This unit is in the southeastern quarter of the county. Bedrock consists of very permeable, cavernous dolomite. Soil thicknesses vary from 0 to 100 feet. Permeability of the bedrock and soil is variable and, in most cases, there is little surface drainage.

Sewage Lagoons. Many problems will be encountered in selecting a suitable site for a sewage lagoon. The cavernous bedrock in this unit is subject to catastrophic collapse, and such collapse could cause serious groundwater pollution. Careful on-site geologic investigation is necessary before any site is chosen for development.

Septic Tanks. Suitable locations for septic tanks are present only in those areas where very deep soils are present. Because of the permeable nature of the residual soil, a thicker than normal soil filter must be present if water pollution is to be avoided. Septic tanks should not be allowed to discharge into sinkholes and, for maximum efficiency, should be restricted to use in rural areas only.

Sewage Treatment Plants. Suitable sites are difficult to locate because of the highly permeable soil. In most cases, remedial measures are needed to prevent groundwater pollution by leaking leachates.

Impoundments. Suitable sites are very difficult to locate. Because of the area's subsurface drainage system, there is almost no surface runoff.

Construction. Problems encountered include variable soil strength and drainage, as well as possible catastrophic collapse.

Unit Four - Carbonate and Cyclic Bedrock (Ca-Cy)

This unit is in northeastern Pulaski County. Bedrock consists of limestone and shale with some sandstone. The soil is less than 40 feet thick and is a silty-clay mixed with some chert.

Sewage Lagoons. Suitable sites for sewage lagoons can be located without too much difficulty. The more impermeable clay soils over shale are best suited for development than are clay soil over permeable limestone. Each proposed site should be geologically investigated before development is begun.

Septic Tanks. Septic tanks can be used in certain cases. Adequate soil depths (20 feet or more) over shale will provide adequate filtering and prevent the effluent from entering the groundwater system. Septic tanks built in thin soils over shale will cause pollution when the effluent surfaces, and septic tanks built in thin soils over limestone will probably leak effluent into the groundwater system. Each proposed site should be geologically investigated before any septic tank construction is begun.

Sewage Treatment Plants. There are few acceptable sites for treatment plants. The soil is not generally thick enough to prevent large volumes of effluent from entering the groundwater system through the permeable limestone bedrock. Careful geologic investigation is needed to determine the feasibility of each proposed project.

Sanitary Landfills. There are few acceptable sites for development as sanitary landfills because of the generally thin soil cover. However, some areas may be acceptable if both cover material and clay padding can be obtained nearby.

Impoundments. Small farm ponds can be developed in areas with thicker clay soil over shale bedrock.

Construction. Problems encountered include locally poor drainage, thin soil, and slope failure.

Unit Five - Intermediate-Thickness Residual Soil Over Sandstone Bedrock (SS-I)

This unit is in the northern half of Pulaski County. Bedrock consists of sandstone, and soil is a stony, silty clay. Thickness of the soil varies from 20 to 40 feet. Catastrophic bedrock collapse may occur.

Sewage Lagoons. Sites suitable for development as sewage lagoons are difficult to locate. The best locations are where soil depths are thickest. The relatively impermeable clay soil provides adequate fluid retention and protection against seepage of effluent into the sandstone. Careful geologic investigation is necessary to determine which sites are best suited for this type of waste disposal.

Septic Tanks. Locating suitable sites for septic-tank development will not be as difficult as locating sites for sewage lagoons. Acceptable sites can be found in those areas where there are at least 15 feet of sandy clay soil. Use of septic tanks should be restricted to rural areas.

Sewage Treatment Plants. Careful geologic investigation is necessary before any proposed site is developed for use as a sewage treatment plant. Discharge points must be chosen carefully, so that effluent is not allowed to permeate the sandstone bedrock.

Sanitary Landfills. The use of sanitary landfills should be restricted to areas with thick clay soil. Ideally, the clay soils should have very little silt or sand. Landfills should be put in relatively flat areas, or in the upper portions of gullies, to avoid occasional flooding. Borrow material needed for stream diversion and cover material may come from nearby, but should not be taken from the immediate area in order to avoid erosion.

Impoundments. The same problems are encountered in locating impoundments as are found when selecting a sewage lagoon site.

Construction. Problems encountered include catastrophic collapse and erosion.

Unit Six - Thick Residual Soil Over Sandstone Bedrock (SS-T)

This unit is in southeastern Pulaski County. Bedrock consists of sandstone and soil cover is thick and is usually a sandy or silty clay. Thicknesses usually vary from 40 to 100 feet.

Sewage Lagoons. Sewage lagoons can be used where clayey or silty clay soil is found. The soil is usually thickest on the hilltops and along bases of hills.

Septic Tanks. Use of septic tanks should be restricted to thick soil areas (20 feet or more). Silty or sandy clays can effectively filter septic tank effluent before it can enter the groundwater system.

Sewage Treatment Plants. Suitable sites for treatment plants are difficult to locate. Careful geologic exploration is necessary to determine if discharged effluent will enter the bedrock before it has been aerated.

Sanitary Landfills. Only those areas in which there are low-permeability soils should be considered for development. Leaking leachates could easily permeate sandy soils, enter bedrock, and possibly cause groundwater pollution.

Impoundments. Difficulties encountered will be the same as for choosing a sewage lagoon site. Small farm pond sites in clayey or silty clay soils may require some remedial measures to insure success. Using bentonite mixed with clay is the most common method of sealing such a site.

Construction. Problems encountered include variable soil permeabilities, possible catastrophic collapse, and hillside erosion.

* * * For additional geologic information concerning Pulaski County see these selected references: 1, 2, 3, 6, 7, 8, 13, 14, 15, 16, 17, 18, 20, 21.

MERAMEC PARK LAKE AREA

(IN PORTIONS OF CRAWFORD, FRANKLIN AND WASHINGTON COUNTIES)

Summary

The area of the proposed Meramec Park Lake is dominated by rugged topography. Relief commonly exceeds 200 feet and may be greater locally. The valley of the area's principal stream, the Meramec River, is generally no more than 1/4 mile wide.

Bedrock units consist of dolomite and sandstone. Loess has been deposited over most of the area. Soils developed from weathered bedrock and loess are of moderate thickness and consist of silty clay and clayey silt.

Recent (1933) earthquake tremors have been felt in the Meramec Park Lake area. However, it is not anticipated that major earthquake activity will occur.

Many caves and springs are present in the region. Onondaga Cave is currently commercialized, and Cathedral Cave is scheduled to open to the public in 1974.

Mineral resources currently produced include iron, sand and gravel. The area has potential for additional iron mining and clay pits. Barite and copper were mined in the past from small deposits.

Water resources are plentiful. At this time, most of the water used within the area is derived from groundwater sources. Well yields vary from 3 to 500 gallons per minute, depending on the aquifer supplying the well. Additional demands for water can be met by utilizing more wells and by using water from the Meramec River.

Proper land use (especially waste disposal) will require careful site selection. On-site investigation is recommended for any proposed waste-disposal project. Sites suitable for development can be found with moderate difficulty. Similar geologic features, resources, and problems will also be encountered in the surrounding area.

It is the intention of this report to serve as a regional appraisal of the geologic features, resources, and problems encountered in the Meramec Park Lake area. It is not intended that this report furnish all the information needed for proper land-use development and it cannot take the place of on-site geologic investigation at each proposed site.

Landforms and Relief

The Meramec Park Lake area has generally rugged topography. The area, at one time a plain, has since been highly dissected by the region's many streams. The remaining landforms are long, ridge-like hills, separated by narrow valleys. Relief varies from 100 to 275 feet. The valley of the area's principal stream, the Meramec River, is generally narrow and seldom exceeds 1/4 mile in width.

Rock and Soil Formations

Bedrock underlying the Meramec Park Lake area consists primarily of dolomite, sandstone, clay, and shale. The dolomite units are more resistent to weathering than the other rock types found in the area and are well exposed where they form steep bluffs along the major streams. A veneer of loess (wind-blown silt) was deposited over the area as glaciers retreated from areas farther north. Thickness of the loess varies from 2 to 5 feet. The soils which have formed from bedrock and loess are of variable thickness and composition. Thicknesses range from 0 to 40 feet and composition varies from silty-clay or clayey-silt to plastic clay. The soils in alluvial valleys are generally thin (0 to 20 feet) and are composed of silt, clay, sand, and gravel.

Earthquake Potential

The bedrock units within the Meramec Park Lake area are gently dipping. Several faults have been mapped within and around the study area. At three of these, the Leasburg fault, the Hamilton Creek fault, and the Anthonies Mill fault, significant bedrock displacement has taken place; often the displacement is of the magnitude of 100 to 200 feet.

Earth tremors, or earthquakes, have occured near or within the region of the study area in modern times. The most recent shocks occured near the Leasburg fault, northwest of Scotia (Ryckman, et al., p. 56). There is some danger of future earthquake activity in the area.

Scenic Natural Features

Many caves and springs are found in the Meramec Park Lake area. Eighty-one caves have been reported, and many of these have been mapped. Two of these caves, Onondaga and Cathedral, are of significant size; Onondaga Cave is currently commercialized, and Cathedral Cave is being reopened to the public. Meramec State Park is dotted with many of these caves and springs. Several large springs are found within the area, in addition to many smaller, but important, springs. The larger springs are Maramec, Westover, Orr and Blue. Maramec Spring is open to the public.

Mineral Resources

The mineral resources of the Meramec Park Lake area are varied. Current mineral production is limited to iron ore, sand and gravel. Stone is produced intermittently. In the past, barite, pyrite, copper, and onyx were mined. However, these deposits were small and either became quickly depleted or were unprofitable to mine. Lead may be present in deep-seated ore bodies, but exploration will be necessary before this can be substantiated.

Iron. Formerly iron ore was produced from ores of pyrite, limonite, and hematite. These ores became unprofitable to mine, and today iron ore is produced from deep-seated magnetite-hematite ore bodies. Meramec Mining Company currently operates a large mine,mill and pellet plant at Pea Ridge near Sullivan. Another large deposit of magnetite-hematite has been located under the city of Bourbon; however, no production is planned for the immediate future.

Barite. Small deposits of barite are commonly found in residual clays in the area. These deposits are of such small size that future production is considered unlikely.

Clay. Deposits of fireclay are often found in sinkhole structures. These clays are suitable for manufacture of fire brick and refractories. Deposits are known in the area of Sullivan and Bourbon; however, there is no current production.

Sand and Gravel. Sand and gravel are produced from alluvial deposits of the Meramec River. They are used in readymix concrete, general construction and road surfacing.

Water Resources

Water for domestic and farm use is obtained principally from groundwater sources. Domestic wells are commonly 100 to 300 feet deep and have yields of 3 to 50 gallons per minute. Industrial and municipal wells are drilled into deeper aquifers. Depths of these wells often exceed 1,000 feet, and yields vary from 70 to 500 gallons per minute. Groundwater levels commonly fluctuate because of seasonal variations in rainfall. The summer months are generally the most productive.

Increased demands for water could easily be met by additional use of groundwater and surface water from the Meramec River.

Land Use

Within the Meramec Park Lake area there are two eingineering bedrock-soil units. These units conform to those designated by Hoffman in Stout and Hoffman (1973). Any consideration of either bedrock or soil cover for development, whether it be for waste disposal, sanitary landfill, impoundment, or construction necessarily must involve the entire unit, not just a part of it.

Unit One - Intermediate-Thickness Residual Soil Over Carbonate Bedrock (Ca-I)

This unit occupies all but the valleys of the major streams. Bedrock consists mainly of dolomite and dolomitic sandstone. Soils range from 0 to 40 feet thick with the greater thicknesses on ridge tops and in valleys. Land-use problems are not insurmountable if proper investigations are carried out to determine the individual limitations of each proposed site.

Sewage Lagoons. Steep hillsides and inadequate soil cover are the major problems encountered. Ideal lagoon sites are at the bases of hills and on ridge tops where soil cover is of sufficient depth. Impermeable clays may be necessary for padding of the lagoon floor. If, during excavation of the lagoon, sandstone or gravel beds are encountered, the lagoon floor should be overexcavated 2 feet and brought back to grade with a compacted clay pad. Grouting may be necessary if problems with fractured rock are anticipated. Leakage from a lagoon could permeate downward to enter and pollute the groundwater system.

Septic Tanks. Unless there is sufficient suitable soil present for dispersal of septic-tank effluent, the groundwater is likely to become polluted. Often, septic tanks have been built in areas where there is not enough soil cover, resulting in the pooling of effluent on the surface. If septic tanks are to be used, they should be restricted to sparsely populated areas such as farms where 3 acres or more per tank are available as a drain field.

Sewage Treatment Plants. In most of the area, streams with large watersheds flow year-round, while smaller creeks may be dry during part of the year. Treatment plants should discharge only into gaining streams with preference given to streams with perennial flow. Some effluent loss may be expected in losing valleys, such as those where the dolomite is highly weathered, or where caves and sinkholes are present. Careful investigation is required before such a plant is built.

Sanitary Landfills. Sites suitable for landfills are difficult to find. In most cases, thin soil is the limiting factor, since soil is needed both as a padding for the landfill floor and as cover material. Suitable sites are locally present on hilltops and at the bases of hills. Depth to bedrock and amount of available soil cover should be determined prior to construction of a landfill.

Impoundments. The same limitations placed on sewage lagoons apply to small impoundments; the major problem is availability of adequate soil for dam construction. Some leakage can be expected in the lake basin by way of solution openings in the bedrock, but these are usually in spots and are not severe or widespread within an entire lake. Pressure grouting may be required to seal the lakes. Smaller lakes can be sealed with clay padding. Soil used for borrow material for a dam should not be taken from the lower part of a valley, because of the possibility of erosion. Areas below springs are often suitable for lakes because of the generally impermeable bedrock and water supply. Site evaluation is needed.

Construction. No serious geological limitations are placed on construction projects. Because developers should avoid areas where sinkholes and cavernous bedrock may affect the stability of multiple-story structures, careful geologic examination should be made before any large buildings are constructed. Though single-family homes are not as limited, they should not be built in sinkholes. Care must be taken to avoid changing the course of groundwater movement, since this could cause collapse of either soil or bedrock.

Unit Two - Alluvial Soil (Al)

Alluvial soil is present in the valley of the Meramec River. Alluvium is from 0 to 30 feet thick and consists of clays, silts, sands, and chert gravels.

Sewage Lagoons. Sewage lagoon use should be discouraged within the floodplain portion of the Meramec valley. Flooding is common, and high river-water levels could also cause rupturing of the lagoon. Areas adjacent to hill slopes are best-suited for development.

Septic Tanks. These should be restricted to rural areas. Danger from flooding is not as great as is possible pollution of surface water or shallow groundwater by improperly operating tanks and possible unfiltered effluent.

Sewage Treatment Plants. Because of frequent flooding, the use of sewage-treatment plants is discouraged.

Sanitary Landfills. Landfills can be built marginal to the alluvial valleys. Problems confronting sewage-lagoon sites will also affect landfill sites.

Construction. Flooding is a problem, and building of any kind on the floodplain should be discouraged.

Impoundments. Small impoundments may be constructed in the floodplain with success. The floor should be lined with clay, and the borrow materials should be composed of impermeable soils. It should be evident that flooding may destroy any dam site. Careful geologic investigation and advice will be necessary at each proposed site before construction takes place.

* * * For additional geologic information concerning the Meramec Park Lake area see these selected references: 2, 3, 6, 7, 8, 13, 14, 15, 16, 17, 18, 20, 21.

JASPER COUNTY, OZARK GATEWAY REGION

Summary

Jasper County has a varied topography. The nothern plains area is relatively flat with shallowly incised streams. The southern part of the county is an area of rolling hills with deeply incised streams. Soil cover is well developed over the entire county, but is much thicker in the south. The county is not considered to be in danger of earthquakes.

Economic mineral deposits of Jasper County at present are almost entirely confined to the stone industry with crushed and dimension stone being produced. The most important stone product by value is marble, which is produced at one quarry in Carthage. Reserves of limestone suitable for the production of high calcium lime are present. Sand and gravel for construction and industrial purposes are currently being processed from mine tailings. There is no production of coal, although the county has minor reserves; oil and gas production is unlikely.

Water supplies for Jasper County, excluding the Joplin area, are currently satisfactory. Supplies of ground water are plentiful in most of the county, but are severely lessened in the immediate Joplin area. Increased demands for water in the Joplin area now place too much of a demand on the current ground water-surface water regimen, and the construction of large impoundments will be necessary.

Engineering properties of the soil and bedrock of Jasper County require careful exploration and study before any sewage lagoon, sanitary landfill, impoundment or structure (of any significant size) be built. Danger of water pollution or structure failure is always greater when construction is done in a haphazard manner. The location of abandoned underground mines (which are prevalent in the area) must be determined if construction is to be avoided in areas with high potential for collapse.

Problems similar to those encountered in the Jasper County area, especially those dealing with the development of water resources and proper land use, affect the four counties - Barton, Dade, Lawrence, and Newton - that adjoin this growth area.

This report is not intended to take the place of on-site geologic investigation, but is intended to serve as a regional appraisal of the geologic problems associated with proper land use development in Jasper County.

Landforms and Relief

The southern portion of Jasper County is an area of gently rolling hills cut by streams flowing to the northwest. Maximum relief (the difference between the elevation of the highest and lowest points) is about 250 feet. The northern portion of the county is typified by relatively flat plains which are dissected by streams flowing to the southwest. Maximum relief is about 100 feet.

Rock and Soil Formations

In the northwestern part of the county the bedrock formations consist of alternating layers of shale, sandstone, limestone and coal, and most of the area is covered with a soil derived from the weathering of the underlying soft shale. In these areas the soil cover may be as thick as 10 feet. The more rugged areas of the northwest are the result of the weathering of more resistant sandstone layers, and the soil cover is generally thinner. In the remainder of the county, soils have developed from weathering of underlying limestones. The soils are red and cherty with thicknesses varying from as little as 20 feet on hilltops to 100 feet in the valleys. Contemporaneous with development of these soils was the nonuniform solution of the limestones to produce solution channels, pinnacles and caves. The nature of the first two forms leads to a soil cover of irregular depth. For the most part, the underlying bedrock (which is well exposed in river and stream valleys) consists of limestones and cherty limestones. In the major stream valleys, there are very small amounts of sand and gravel present as alluvial deposits.

Earthquake Potential

The bedrock, in Jasper County, in most cases dips very gently to the west and thus appears to be horizontal when seen at outcrops. There are several faulted areas within the county, but in most cases the displacement is only a few tens of feet. None of the faults are known to have been active. Folding of bedrock is common but the resulting dips are slight and are usually found to be steeper in faulted areas than in gently folded and unfaulted rock units. Streamflow is generally controlled by the fracture systems, faults and joints that have developed within the strata. This area is not considered to be earthquake-prone.

Scenic Natural Resources

Many small springs and caves are found in the Jasper County area. Twenty-two caves have been reported, and although none of these are now commercially operated, Crystal Cave was at one time a dance hall.

There are no large springs in Jasper County.

Mineral Resources

Jasper County was an active partner in the formerly very productive Tri-State zinc-lead mining industry during the late 19th and early 20th centuries. The mines are shut down at present with only low-grade reserves remaining and prospects for reopening are unlikely. Both surface and underground mines are now filled with water creating a safety hazard. The tailings, once a waste product, of this extensive mining operation are now a source for exploitation as sand and gravel. The mill tailings, or "chats", are now processed for use as construction sand and gravel and for industrial uses such as grinding and polishing. The particle size of the product is usually one-half inch or less. About 1 million short tons of "chats" are in reserve in the Jasper-Newton County areas.

Stone. This is the most important product in Jasper County's mineral industry. Both crushed limestone and dimension limestone are produced. Crushed stone uses are agricultural limestone and construction aggregates. Because of high chert content, much of the limestone in Jasper County is not quarried. Dimension stone is quarried and processed by the Carthage Marble Corp. and sold as rough-cut and finished marble slabs for building, decorative and monument stone. The company produces both crushed stone and dimension marble from a quarry at Carthage, and dimension blocks at a quarry in Newton County. Three other companies, Independent Gravel, Joplin Stone and Nelson & Son, produce crushed stone at quarries located near Carthage, Duenweg and Jasper, respectively. The Joplin market is also supplied by the Mattes Brothers Quarry, on the southwest edge of Joplin, in Newton County.

Lime. Lime was manufactured in the county during the late 19th and early 20th centuries. In 1910, three plants were operating within the county at Sarcoxie, Carthage and Joplin, but by 1915 production had ceased. There are considerable reserves of limestone suitable for the production of high-calcium lime in Jasper County. The determining factors for consideration in redeveloping the industry are market areas and adequate transportation facilities.

Sand and Gravel. Neither sand nor gravel is being produced from alluvial (stream) deposits, and such an operation in the future would seem inadvisable because of the meager supply available. The best source of sand and gravel appears to be processed "chats", as mentioned before. "Chats" are composed of jasperoid chert. Because of the closing of the Tri-State mining district, "chats" are no longer produced as waste material and, as a result, supplies are being depleted.

Coal. Although no longer mined in Jasper County, slightly more than 100,000 tons of coal have been produced in the past, and an estimated resource of 93.6 million tons remains in a very thin seam in the northwestern corner of the county. This includes a mineable reserve of 5.8 million tons. The Empire District Electric Company's mine-mouth power plant at Asbury in the northwestern corner of the county provides a market for some potential production of Jasper County coal.

Potential for oil and gas production within the county appears to be dim. Although some near-surface formations contain hydrocarbons, they are not extensive enough for commercial production. Data indicate that there are no oil or gas accumulations below about 400 feet.

Water Resources

Surface Water. The two principal streams draining the county are Spring River and Center Creek. Without some form of control on their flow, these streams are incapable of supplying needs much greater than current usages. The city of Joplin is the principal user of surface water at present. With controlled discharge of these two streams by a series of dams, there would be an adequate supply of water for a manyfold increase of present consumption. The quality of the streams varies depending on the runoff from their many tributaries. Several of these flow through the old zinc-lead mining areas. Through oxidation of the sulfides remaining in the bedrock, much of the ground water in the area is polluted and upon discharge into the streams it has degraded the quality of the water. In some stretches the water is very acidic and is high in iron, sulfates, lead and zinc. Low-flow characteristics of these streams preclude dilution of waste materials from sewage-disposal plants. With reservoirs, these waters could be sufficiently diluted to be of acceptable quality.

Ground Water. The supply of ground water in Jasper County comes from two contrasting environments. That nearest the surface is contained in a "shallow" aquifer of Mississippian age and the other comes from a "deep" aquifer of Cambrian-Ordovician age.

There is a great deal of variation in the quality and quantity of water within the shallow aquifer. The foremost reasons for this are the mineralization of the bedrock and the history of mining. In spite of the oxidation of sulfides, not all of the water is of poor quality and much of it, which can be termed good, is used for industrial purposes. Caution should be used prior to utilization of waters filling the mine-workings, with an investigation being made to determine the amount of water available and its quality. Many places within the Mississippian formations contain brecciated-chert zones. The resultant rock materials generally have water yielding capabilities of 10 times, or even 100 times, greater than areas without this brecciated chert. Again, if such highly productive zones are discovered, care should be exercised in evaluating their ability to continue to produce at high rates.

Springs flowing from the Mississippian aquifer show the same variations in amounts and water quality as the mine-workings water.

Most home wells in Jasper County obtain their supply of water from the Mississippian aquifer. Those wells protected from surface pollutants by adequate construction and which are not influenced by mine-workings are generally sources of good water. Now that the mines have ceased to operate, water levels are more stable and thus the system as a water source is much more reliable than it was several years ago.

Recharge, or replenishment, of this aquifer system is accomplished directly and quickly from precipitation. The very openness of the ground, which permits this rapid recharge, also makes this aquifer system readily susceptible to pollution. Increasing population in rural communities in the county will, unfortunately, lead to a degradation in water quality because of additional septic tank discharge. Fortunately, the ground-water movement is primarily with the topography of the land; that is, the ground water will move from higher elevations toward the streams where it will be discharged. This movement is often modified by geological structural features such as faults and shear zones which act as directional guides. Thus, pollution can be avoided in many cases by placing wells uphill from the potential source of pollution.

The Cambrian-Ordovician "deep" aquifer is separated from the Mississippian aquifer by a layer of "tight" silts and shales with very low permeability. The water is seldom polluted from oxidizing sulfides. In the few locations where pollution does occur, the ground water from the shallow aquifer has had an avenue for entering the deep aquifer. Generally, this happens when there is insufficient casing plus enough time lapse for corrosion to perforate the casing. Polluted water from above can then move down through the casing to the deeper aquifer. When the point of entry is not in the well structure itself, it is exceedingly difficult to identify where contaminants are being introduced. This problem occurred at the Junge Bakery well in Joplin and deeper casing did not succeed in excluding this bad water. At Webb City, a similar problem was solved by recasing and grouting; however, another well could not be saved since the point of entrance could not be found. All abandoned wells, especially those that penetrate the deep aquifer, should be plugged. This was attempted during the 1930's, but some wells were never located and so could not be sealed. The quality of the water from the deep aquifer has good characteristics with chlorides and sulfates being low. Dissolved solids are generally less than 200 parts per million, and hardness is usually less than 150 parts per million. Recharge of the deep aquifer is somewhat limited since the shales above permit very little downward seepage except in areas of faulting and jointing. Most recharge is lateral, with the water moving from east to west.

Industrial wells and municipal wells go as deep as 1,800+ feet, but only a few are more than 1,400 feet deep. In and around Joplin, yields are small compared to those that can be obtained at Carthage. In Joplin, yields are close to 150 gallons per minute and only very rarely are they more than this. At Carthage, yields are around 400 gallons per minute, and Empire District Electric Company has been able to obtain 900 gallons per minute from individual wells in northwest Jasper County.

Excluding the Joplin area, a manyfold increase in ground water consumption can be maintained. The only significant source of water for a growing Joplin area is surface water collected in impoundments.

Land Use

Because geologic processes have been most important in the development of physical characteristics of surface bedrock and associated soil, areas with similar engineering-geologic features partially coincide with the physiographic in Jasper County. With regard to construction, development and waste disposal, it is therefore necessary to consider the bedrock and soil as a single unit and not separately. Three engineering-geologic units are present in Jasper County. These units conform to those designated by Hoffman in Stout and Hoffman (1973) and used on the Engineering Geology map.

Unit One - Cyclic Sedimentary Bedrock (Cy)

Unit one is located in northwestern Jasper County. The bedrock units consist of alternating shale and limestone with some coal and sandstone layers. Soils are developed on the bedrock surface and vary from a silty clay to sandy clay. Thicknesses are generally less than 10 feet.

Sewage Lagoons. The general watertightness of the soil and bedrock affectively reduces pollution making lagoon construction feasible when other conditions are favorable. If sandstones are exposed during excavation, routine remedial procedures of undercutting and padding will be necessary and can be done without excessive costs.

Septic Tanks. These should not be used in densely populated areas. The discharge from these tanks do not permeate the host rock well enough to be adequately dispersed and can result in water standing around foundations and possibly puddling in low areas and ditches. In general, a three-acre seepage field should be allotted for each septic tank to assure proper dispersal of pollutants.

Sewage Treatment Plants. Suitable sites for receiving discharged effluent can be located with little difficulty. In most cases there is little loss of stream water to bedrock and, because of this, the areas streams ideal receivers of treated effluent. Careful investigation will be necessary to determine the suitability of each proposed site for this type of waste disposal.

Sanitary Landfills. Pollution from a correctly located and properly operated landfill will be minimal. Ideal locations can be found in the smaller creek valleys. However, diversion ditches will be necessary to prevent flooding of the landfill site and subsequent stream pollution.

Impoundments. Lake development is most favorable in this plains area with seepage problems being minimal where there are underlain clayey or shaly soils. Sandstone regions pose a greater hazard because of probable seepage through fractures. Leakage is also possible along coal seams and limestone layers. These problems can be overcome by core trenching to unweathered bedrock, careful borrow-site selections and occasional soil blanketing. Severe problems might be encountered where many sandstone exposures are present.

Construction. Significant problems associated with construction in northwestern Jasper County include expansion of the clayey soils. Proper drains and deeply seated foundations will overcome this problem.

Unit Two - Variable-Thickness Soil Over Carbonate Bedrock (Ca-V)

This unit is located in the southern and northeastern parts of Jasper County. The bedrock consists of permeable limestone which has weathered to produce karst. Soil cover has developed over the bedrock and is generally a red stoney clay soil. Both bedrock and soil are highly permeable with much surface water being lost by seepage. Soil thicknesses vary from 0 to 40 feet.

Sewage Lagoons. Waste disposal by lagoons is hazardous because of seepage problems, particularly into caves and solution channels. Sewage lagoons built above voids such as caves, also have the potential of collapsing into the caves and contaminating the ground water.

Septic Tanks. Disposal by septic tanks poses similar problems. The discharge, if not filtered or retained, but allowed to enter shallow ground water supplies, may cause pollution and eventual loss of water for home and farm uses. Sinkholes or caves are not to be used for waste disposal of any type. The numerous caves and their subsurface streams readily transmit contaminants as do surface streams.

Sewage Treatment Plants. Discharge of treated effluent should be made only into gaining streams. Careful investigation will be necessary to insure that effluent does not enter the ground water system through sinkholes that may be present in the area.

Sanitary Landfills. Landfill sites must be carefully selected because of potential seepage problems. Soil thickness, in many cases, will be insufficient and leachates may leak directly into bedrock and cause pollution of the areas ground water resources.

Impoundments. There are few areas within this unit that are suitable for lake development. Vertical loss of water both in the watershed and lake area and poor foundation conditions at the dam site contribute to the failure of many lakes. One of the few suitable areas is in the upland-soil region where small lakes are feasible if necessary precautions are taken, including the careful selection of borrow sites. There are some potential sites for large lakes along major streams where there is perennial flow.

The most unsuitable areas for lake sites lie on the slopes between upland prairies and the major streams. The ground water table in these areas is relatively low, the fine-textured soils have been removed by surface erosion, and suitable foundations for dam sites have been destroyed by weathering.

Construction. Generally the overburden and bedrock will support building construction if normal precautions are taken. However, there are two unusual features which have a great effect on roads and construction. The first is that the red clayey soils are hard to compact and, second, the underlying limestone is irregularly pinnacled so depths to bedrock fluctuate severely. Careful subsurface exploration is necessary for foundations of larger structures.

Unit Three - Alluvial Soil (Al)

This unit is not shown on the Stout and Hoffman map because of the units small size. The unit occupies the alluvial valleys of the county's major streams, Spring River and Center Creek. These valleys are deep and narrow in eastern Jasper County and become wide and flat in the Joplin area. Soil thicknesses vary from 0 to 40 feet. The soil is an admixture of gravel, sand, silt and clay.

Sewage Lagoons. The construction of a lagoon in this unit may lead to flooding of upstream developments as well as pollution of downstream waters. Therefore, great care should be taken in selecting a lagoon site.

Septic Tanks. Septic tanks can be used in this unit with caution. Groundwater supplies are easily contaminated by improperly filtered septic tank effluent. Septic tanks could be used in rural areas where a minimum three acre-field is available for filtration.

Sewage Treatment Plants. Treatment plants can be utilized if discharge is limited to gaining streams.

Impoundments. Lakes can be constructed with some difficulty. The dam-site will have to be over excavated at the base and sides to insure that no leakage will take place around the dam. If permeable bedrock is encountered the project may not be feasible because of increased costs.

Construction. Problems most often encountered include flooding, seepage and varying soil strength.

* * * For additional geologic information concerning Jasper County see these selected references: 1, 2, 3, 4, 5, 6, 7, 8, 13, 14, 15, 16, 17, 18, 20, 21.

GREENE COUNTY, LAKES COUNTRY REGION

Summary

Greene County, located in southwestern Missouri, is an important growth area. The city of Springfield is rapidly developing, and decisions involving proper land use, within and particularly outside of the city, will greatly influence the further development of the county.

The physiography of Greene County reflects the character of the underlying bedrock. For the most part the topography is gentle; only in the northern and James River areas does the topography become more severe. Slopes are greatest in the north and east. Soil cover is thick to non-existent and will create problems with liquid-waste disposal because of indadequate soil cover to absorb and filter septic-tank effluent; slopes are often too steep for the safe construction of sewage lagoons.

Valleys and their floodplains are subject to periodic flooding. The James River is more prone to flooding than other streams. Flooding can occur in any valley, with or without normal stream flow. Because of this problem, sewage lagoons built on floodplains must be protected from inundation by flood waters. If water levels should rise above the level of the lagoon, the lagoon floor will most likely rupture and create a pollution problem. Construction of homes and other buildings should be discouraged on floodplains prone to flooding.

Bedrock underlying most of Greene County is composed of limestone, with isolated or restricted occurrences of dolomite, shale, and sandstone. This limestone bedrock is prone to solution activity of both surface water and groundwater. Large caves and solution channels have been developed in the Burlington Limestone. Sinkholes are well developed over cavernous rock. Actions by man that interfere with normal water movements may cause collapse of these structures and possible pollution of groundwater. Impoundments, waste-disposal sites, and dwellings should not be built in sinkhole regions without careful investigation. Careful investigation should be made to determine if wate impounded in stream valleys and topographic lows will be lost to the subterranean water system. Limestone of the Burlington Formation is often unevenly dissolved by surface waters, resulting in a pinnacled

surface. Often these pinnacles have 5 to 15 feet or more of relief. Wherever Burlington limestone is near the surface, the presence of pinnacles should be anticipated. Geologic investigation is recommended before construction is considered. It is necessary that pilings of buildings be either all on bedrock or all on soil, but never both. Differential settling and tipping will occur if the foundations are not properly seated.

Bedrock other than limestone presents less of a problem to the developer and planner. Dolomites are less affected by solution activity in this area and present no special problem. Sandstones occur either as thin lenses within the dolomite or as isolated strata on hilltops. No special problems are encountered, other than when constructing waste-disposal facilities, especially sewage lagoons and sanitary landfills. In these cases, the sandstone must be undercut about 2 feet and packed with clay sealant to prevent leakage and possible water pollution. Shales present a problem in almost all cases. Slopes developed on the Northview Formation are usually too steep for buildings larger than single-family homes. Buildings larger than this must be supported on piles or sliding will occur. Sewage lagoons and landfills can be built successfully on these slopes.

Soils are well-developed over most of the county, with depths ranging from 0 to 40 feet, depending on the type of bedrock. Geologic investigation will be necessary to determine exact depths and characteristics of the soils present at each proposed site. Many soils, although rich in clay materials, are unsuitable where water retention is necessary. Soda ash can be mixed with these clays to create an impermeable soil. Also, brownish clays mixed with bentonite can be used.

The principal mineral resource of Greene County is limestone. Both crushed and broken stone and dimension stone are produced. Crushed and broken stone is used for aggregate, aglime, and manufacturing lime. Demands can be expected to increase. Dimension blocks are produced near Phoenix by Carthage Marble Corporation and shipped to Carthage for finishing. As an example of multiple land use, the Griesemer Stone Company underground quarry near Springfield is used as a warehouse for cold storage.

Water resources for Greene County, and especially Springfield, are fast becoming inadequate. Only by extensive planning and utilization of both surface water and groundwater can the area hope to develop a water supply which will be adequate for the next 20 to 30 years. Additional development of groundwater supplies and treatment facilities for currently unacceptable groundwater are needed. Future impoundments on the James River and others will probably be necessary.

Disposal of wastes by treatment plants will become more and more necessary. Discharge points and streams have to be carefully chosen to avoid pollution of the groundwater system, especially in karst areas such as Springfield.

Problems encountered with geologically oriented development in Greene County extend beyond the county's boundaries and are found in the four adjacent counties.

This report is intended to serve as a regional appraisal of the county's geologic features, resources, and problems and is not intended to supply all the information needed for development. In all cases, careful geologic investigation of proposed development sites is advised, so that alternate sites can be used when necessary, and so that necessary precautions are taken to insure the stability of each project completed.

Landforms and Relief

The topography of southern Greene County is one of wide, rolling hills. Meandering streams usually are incised into the plateau about 70 feet, but may be cut in as deep as 125 feet. Slopes are gentle, except in bluffs, where they are frequently nearly vertical. The floodplains are generally 1/3-mile or less in width. Maximum relief is about 300 feet. Numerous sinkholes are scattered about.

The topography of northern Greene County is more rugged. Streams have severely dissected the plateau and become entrenched, thus forming numerous hills and prominent ridges. These moderately incised streams have developed narrow floodplains. The streams are incised about 150 feet. Slopes are often gentle, but become much steeper near the numerous valleys. Relief is commonly 75 to 100 feet, while maximum relief is about 300 feet. Sinkholes are common.

Rock and Soil Formations

The bedrock of Greene County is varied. Limestone and cherty limestone crop out or form the near-surface bedrock over about 90 per cent of the county. The remaining 10 per cent consists mainly of dolomite, with some shale, sandstone, and conglomerate in isolated occurrences. The dolomite is limited to the north-central, northwestern, and eastern parts of the county. The dolomite forms a broad, undulating surface which has been dissected by the many streams. The subsequent weathering of the dolomite has produced a fairly thick soil cover. The soil is a red, slightly cherty clay.

Limestone bedrock is covered with soil of variable depth. In general, the type of soil cover reflects the character of the bedrock. The limestones have weathered easily. Sinkholes, caves, solution channels, and pinnacles have been formed by the action of water on the bedrock. Shapes and sizes of the pinnacles are highly irregular, resulting in unpredictable soil thickness. The limestone is very porous and permeable and loses downward-percolating surface water to the underlying formations and springs. Soils developed from the weathered limestone are of a red, cherty clay. The clay is usually a poor material for water retention because of its high permeability and porosity, due possibly to the high iron content of the clays. Thickness of this soil averages 10 feet, but differences in thickness of 10 to 20 feet in a 5-foot lateral direction are common.

Some of the limestone units weather rather uniformly and produce a very cherty, red-clay soil. Soil cover is generally 15 to 20 feet thick. Exposures and soil-covered areas are usually restricted to valleys where streams have cut down to expose them and in faulted areas where the formation has been uplifted to form hills.

The remaining limestone units crop out to a much lesser extent. Some of the limestone is quite porous and permeable. Springs are common.

Shales and siltstones cropping out in Greene County have very little porosity or permeability. They weather to a thin, clayey soil.

Alluvial deposits of recent age form narrow outcrops in Greene County valleys. Floodplains are usually only 1/8- to 1/5-mile wide, and deposits are rather limited. The James River valley floodplain, however, is 1/3- to 1/2-mile wide, and fairly extensive deposits of alluvium are present. Composition is variable. Silts, clays, sands, and gravels are present. Deposits are generally from 0 to 20 feet thick but may be as much as 40 feet thick.

Earthquake Potential

Strata in Greene County dip to the southwest at 40 feet per mile, or less than 1 degree. In many areas this dip has been disturbed by faulting. Several faults with a northwest-trending strike cut across the county. Several east-west faults are also present, but these do not have the same lateral extent. A major anticlinal fold extends from southwestern Greene County to the northeastern part of the county, intersecting Springfield. No faults run through Springfield. Earthquake activity in this area is minor, and little except minor tremors have occurred in the historical past.

Scenic Natural Resources

Many caves and springs are found in the Greene County region. Two-hundred and thirty-two caves are reported, and two of these, Fantastic Caverns and Crystal Cave, are commercialized. Four large springs are reported. Total daily discharge averages 7 million gallons. Sequoita Spring near Springfield supplies water to a fish hatchery. The spring is picturesque and can be visited by the public. Many smaller springs can be found in the county.

Mineral Resources

The mineral industry of Greene County is centered around limestone. There are no known major deposits of metallic ores.

Stone. Greene County is a major producer of crushed and broken stone. Four quarries are active and produce from the Burlington-Keokuk Formation. Principal uses are for aggregate in readymix concrete and construction, aglime, and lime manufacture.

Dimension stone quarried in northwestern Greene County near Phoenix is shipped to Carthage for finishing.

Lime is manufactured at the Ash Grove Cement Company's Galloway plant south of Springfield. The Burlington-Keokuk is again the best source of high-calcium lime in the area, containing an 80-foot thickness of stone suitable for lime manufacture.

Sand and Gravel. Sand and gravel are not present in commercial quantities.

Water Resources

Needs for water are currently being met in Greene County by utilization of both surface and groundwater.

The principal sources of surface water are the Sac River, Little Sac River, and the James River. The city of Springfield currently obtains much of its water supply from the James and Little Sac Rivers. Three impoundments are utilized to collect water for the city. Water from the James River impoundment is primarily used for cooling purposes for power-generation plants. Impoundments on the Little Sac River, Lake Fellows, and McDaniel Lake supply much of Springfield's potable-water-supply needs. Their capabilities to deliver water are nearing full utilization. Preliminary studies suggest the economic feasibility of constructing an additional impoundment on the James River, to be located partially in Greene County and partially in Webster County. This has been referred to as the County-Line Dam proposal. Springs of significant size are present in Greene County. Fulbright Springs has been used as a water source for Springfield for a period of many years. Spring water in Greene County is extremely vulnerable to pollution induced by man's activities on the land surface. Several springs are grossly polluted by either septic-tank effluent or discharge from city treatment plants. The small size of the area's streams and their low-flow characteristics lead to problems in maintaining the desired water quality when they are the recipients of sewage-plant discharge.

Small cities use groundwater almost exclusively. Well depths are as much as 1,200 feet. Casing depths are as much as 500 feet. To date, this amount of casing has assured the exclusion of surface pollutants. Municipal wells, owned by Springfield and industrial wells in and adjacent to Springfield have maximum depths of 1,400 feet. These wells, in Ordovician aquifers, have high yield capabilities. Yields in excess of 1,000 gallons per minute are common. At that rate, drawdown is no more than 100 feet. Over the last 40-year period, water levels in the Springfield area have been depressed by 350 feet. Locally, pumping levels are now below 600 feet. Maximum pumping is experienced during the summer months. Drawdown decreases in the winter months, and the aquifer is recharged; pumping levels recover by as much as 150 feet. Formerly, recharge of the aquifer was from the east, but now because of the great demand placed on the aquifer, recharge is from all directions. Precipitation was once the principal source of recharge. This has largely been supplanted by laterally moving groundwaters. Vertical movement is limited by the Northview and Cotter Formations, which prevent any further downward movement of the water. While this does limit recharge by surface water to the lower aquifer, it also prevents futher penetration by pollutants which have penetrated to the Mississippian aquifers. The chemical quality of this water is good; sulfates are below 10 parts per million; chlorides below 5 ppm; total dissolved solids about 200 ppm; and total hardness 160 ppm.

The Mississippian aquifers have been much used in past years for private wells. Wells have depths ranging from 100 to 400 feet. The water formerly was of good quality, but with the increasing impact of urbanization, problems of pollution have become so frequent that it is generally recommended that the entire series of Mississippian rocks and the uppermost part of the Ordovician formations be excluded by casing, and that this casing be sealed by grout or bentonite to prevent the movement of pollutants down the well structure itself. By excluding these upper aquifers, the quality of the water is comparable to that obtained by the deep wells. Many of these private wells penetrate to depths of 700 feet or more. Without mandatory standards placed on well construction, it is doubtful that quality will be maintained. Those wells improperly constructed and penetrating to equal depths will be avenues for the polluted upper waters to gain access to the deeper aquifers. Currently there are no standards except for public-water-supply wells.

One can only view the future with apprehension as it pertains to the quality of water in Greene County. Even if strict standards are imposed on the construction of wells in the future, the wells now in existence preclude optimism concerning encroachment of pollutants.

More and more, it will become necessary for groundwater to be treated to make it safe and potable. Adequate supplies of water of suitable quality can only be obtained by the development of additional sources.

Land Use

The study of surface features, soils, bedrock, groundwater, and past geologic history play an important part in determining proper land use. In general, Greene County can be divided into five units for engineering-geologic (or land-use) purposes.

Unit One - Karst (Ca-K)

Carbonates underlie most of central Greene County. Several soils have developed and although quite similar, there are a few major differences. Bedrock is often pinnacled and cavernous and covered with either a red, sticky, cherty-clay or red, very cherty, clay soil. Thickness of this soil cover varies from 0 to 100 feet.

Sewage Lagoons. Construction of lagoons in this limestone-soil unit should be done with caution. Because of pinnacles, the thickness of soil cover is very irregulat. Lagoons built above voids such as caves, could possibly collapse and release sewage into the groundwater system. Each proposed site should be carefully investigated.

Deep excavations for lagoon sites may intersect these solution phenomena, gravels, or permeable red clay. It is recommended that excavation depths be kept to a minimum and that if gravel pockets are encountered they be overexcavated to a depth of 2 feet and replaced with compacted clays. The red clays of this area are unsuitable because of their permeability; however, they will become impermeable when treated with soda ash. A mixture of brownish clays and bentonite is also a good sealant. Lagoons should not be constructed in areas located over voids such as caves.

Septic Tanks. The soils in this area are very porous and permeable. With the discharge of sewage waters from septic tanks, clay structure will be further destroyed and permeability increased. As a result of increased permeability, septic-tank discharge is not properly filtered. This relatively untreated effluent can then enter joints in a weathered bedrock, fractures, or bedding planes and move laterally for long distances. Septic-tank effluent is also likely to enter caves and solution channels where openings occur near discharge points. Septic tanks are to be discouraged in densely populated areas, but are acceptable on farms and other rural homesites where there are three acres or more per tank for discharge.

Sewage Treatment Plants. Observations should be made to determine the presence of caves and sinkholes in all areas under consideration as discharge points. Losing streams are numerous, and possibilities are great that effluent will enter the groundwater system.

Sanitary Landfills. Soils in this unit are of sufficient depth in many areas. Each proposed site should be examined geologically to avoid using a site that may collapse. Because soil permeability is great, clay sealant will be necessary to prevent leakage of polluted waters into the surrounding soil and underlying bedrock. The use of sinkholes and abandoned mine shafts is to be discouraged. Possible sites for sanitary landfills exist in upland valleys and gullies. Clay materials adequate for cover should be present. It may be necessary to construct small retention dams where landfills are built to hold back untreated leachates flowing from the landfills site.

Impoundments. The same problems with constructing a sewage lagoon will be encountered.

Construction. Soils of this unit possess adequate strength to support small or medium-sized buildings. Construction of large or multiple-story buildings, however, will necessitate excavation. When footings or piers are necessary, it is mandatory that they all be located on bedrock or soil and that no combination be used. Soils in this unit may compact under great weight, and differential settling could occur. If the building were constructed with some pilings on pinnacled bedrock and some on soil, the building would be left sitting lopsided after compaction of the soils. Careful geologic investigation is necessary to insure proper site selection.

Unit Two - Carbonate Bedrock With Some Shale (Ca-Sh)

Bedrock units consist primarily of shales, siltstones, and carbonates that crop out only in scattered areas and along hillsides in northerr and eastern Greene County. Soils are thin because they form on slopes and thicknesses range from 0 to 30 feet. Careful geologic investigation is necessary to determine if adequate soil cover is available and whether fractures or joint systems are present. The soils vary from clay to sandy clay.

Sewage Lagoons. These should be kept quite shallow and restricted to the shale and the clay soils derived from it. The shale is quite impermeable and because of this is an ideal unit to place lagoons in. Seepage can be controlled so as to restrict pollution of water supplies.

Septic Tanks. These are desirable only on farms and sparsely populated areas. Three acres per tank is ideal for proper filtration of the effluent. Discharge points should be kept restricted to the soils of the Compton Formation. The Northview will not readily filter effluent and will cause surface pollution. The Pierson is quite permeable and would allow effluent to seep through and contaminate Northview springs.

Sewage Treatment Plants. Discharge of treated effluent is not recommended. Most streams have low-flow for most of the year, and therefore effluent would undergo inadequate dilution.

Sanitary Landfills. The shale portion is ideal for sanitary landfills. Because outcrops are limited, size of the landfills will have to be kept small. Diversion ditches may be needed to keep surface water away from the fill site, and it may be necessary to construct small retention dams at the foot of the landfill to trap leachates.

Impoundments. The clayey soils are well-suited for the construction of small impoundments. Sites should be examined to determine if sufficient soil cover is present. When the soil is thin over limestones, especially the Compton, much water may be lost to bedding-plane fractures. Any site being considered for an impoundment should be examined geologically.

Construction. Except on steep slopes, there should be no problem in using the land for a housing development. On steep slopes, slides may occur. A geological investigation should be carried out before construction of any building larger than a single-family dwelling to determine the condition of bedrock and soil.

Unit Three - Intermediate-Thickness Residual Soil Over Carbonate Bedrock (Ca-I)

This unit is in the north and eastern portions of Greene County. The dolomite bedrock is cherty, with some sandstone stringers. Soil consists of reddish, cherty or sandy clays, from 0 to 10 feet thick. In general, the dolomite have not weathered to produce karst.

Sewage Lagoons. Shallow lagoons can be safely constructed in this unit. Soils are generally of sufficient thickness on hilltops. Excavation should allow for a blanket of 3 feet of clay over the bedrock to allow for control of downward seepage. Lagoon sites over sandstone stringers will require that a portion of this sandstone be removed and that the site be sealed with clay before being used.

Septic Tanks. There can be used successfully in rural areas where 3 or more acres per tank is available for proper filtration of the effluent.

Sewage Treatment Plants. Treated effluent can be discharged safely into many of the area's streams. Most of the streams have low flow, but few are losing. Some loss of effluent may occur in areas of local karst.

Sanitary Landfills. Soils of this unit are adequate for shallow landfills. Careful geologic investigation is required before a site is developed. Adequate soil must be available for use as a buffer between bedrock and the fill and as cover material. Generally, only hilltops, and in some cases areas at the bases of hills provide sufficient material for landfills.

Impoundments. Impoundments of small size can be safely and successfully constructed on slopes in the small valleys in this unit. Sufficient soil cover is needed for use as a buffer between bedrock and the pond and as a dam-fill material.

Construction. Both soil types and bedrock are suitable for construction. Single-family dwellings can be built almost anywhere if some precautions are taken, especially in areas on hillsides where some sliding may occur. Large buildings should only be built after a careful geologic examination has been completed to determine bedrock and soil characteristics at each proposed site.

Unit Four - Variable Soil Thickness Over Massive Carbonate Bedrock (Ca-V)

This unit is in southwestern, northern and eastern portions of Greene County. The bedrock is limestone and is a firm, competent unit, unless caves and near-surface, solution-enlarged openings are extensive. Soil cover is 20 to 30 feet thick but may vary locally.

Sewage Lagoons. Sewage lagoons require careful construction. Careful site selection and thorough subsurface investigation are strongly advised. The subsurface soil and bedrock often contain caves, pinnacles, and solution channels. Lagoons built above one of these voids could possibly cause collapse of the bedrock roof with loss of sewage into the underground strata and pollution of any groundwater in these strata. Lagoons built in this unit should be lined with impermeable clays; the red clays associated with this soil can be used, but may require special sealants. Brown clays mixed with bentonite provide the most suitable liners for lagoons.

Septic Tanks. Waste disposal is a difficult problem due either to insufficient or inadequate soil cover. Clays in this unit have been drived from weathered bedrock. Septic-tank effluent will seep rapidly through this clay soil, thus reaching groundwater. As a result of this high permeability, the effluent will not be filtered properly. These relatively untreated waters can enter weathered joints and bedding planes in the bedrock and move laterally and vertically for long distances from their original points of discharge. Use of septic tanks should be restricted to farms to avoid concentration of effluent in the soil and possible groundwater contamination.

Sewage Treatment Plants. Sewage treatment-plant effluent can be discharged safely in a few areas where plentiful surface water is available for dilution. However, many receiving streams lose surface flow to the subsurface. Thus, they must be thoroughly explored to determine the extent of this possible hazard to groundwater supplies. An example is the Wilson Creek-Rader Spring system, where effluent discharged upstream entered the groundwater system and resurged at Wilson Spring, back into Wilson Creek. Treatment plants should be located only in areas where such a problem is unlikely.

Sanitary Landfills. Sanitary landfills should not be built without prior geologic investigation. The practice of using sinkholes and abandoned mine shafts as waste-disposal dumps should be strongly discouraged. Inadequate amounts of proper fill material hinder operations over much of this area. Sites can be located where bedrock has contributed to development of more impermeable soils.

Impoundments. The development of lakes in this area is feasible because of good stream flow. While there is relatively little water loss to bedrock if precautions are taken, leakage into bedrock and soil is a likely hazard. Many sites have either inadequate or unsuitable borrow material for dams.

Construction. Construction poses a problem only in those cases where much fill material is needed, such as in construction of large buildings or roads. Red-clay soils perform poorly in compacted fills.

Unit Five - Alluvial Soil (Al)

Alluvial valleys of significant size are present in most areas of Greene County. Alluvium is from 0 to 20 feet thick and consists of clay, silts, sands and chert gravels.

Sewage Lagoons. These can be built with little difficulty. The lagoon should be shallow, and its floor should not be in sand or gravels, but in a compacted soil of clays and silts. The floor should be excavated only a few feet, or water contained in the alluvium will weaken and rupture the floor. Provision must be made for protection from flooding.

Septic Tanks. These should be restricted to rural areas. Danger from flooding is not as great as is possible pollution of surface water or shallow groundwater by improperly operating tanks and possible unfiltered effluent.

Sewage Treatment Plants. Sites suitable for discharging effluent can be found with some difficulty. Care must be taken to prevent effluent from entering the groundwater system.

Sanitary Landfills. Landfills can be built marginal to the alluvial valleys. Problems confronting sewage-lagoon sites will also affect landfill sites.

Impoundments. Small impoundments may be constructed in the floodplain with success. The floor should be lined with clay and the borrow materials should be composed of impermeable soils. It should be evident that flooding may destroy any dam site. Large impoundments have been constructed in some alluvial valleys, such as that of the James River. Careful geologic investigation and advice will be necessary at each proposed site before construction takes place.

Construction. This should be restricted to single-family dwellings. If flooding is a problem or has been a problem, buildings of any kind should be discouraged.

* * * For additional geologic information concerning Greene County see these selected references: 1, 2, 3, 6, 7, 8, 13, 14, 15, 16, 17, 18, 19, 20, 21.

CAPE GIRARDEAU COUNTY, SOUTHEAST MISSOURI REGION

Summary

Cape Girardeau County lies along the Mississippi River in southeastern Missouri. The area for the most part is hilly, with gentle slopes, except along the Mississippi River, where steep bluffs are present. The southern part of the county was once an alluvial valley and is quite flat. Floodplains are narrow and may experience some flash flooding.

Bedrock consists of dolomite, sandstone, limestone and shale, all of which crop out within the county. Soils covering bedrock are also varied, reflecting the type of rock from which they were weathered. A deposit of loess (windblown silt) covers much of the county, in addition to the soils present. Soil cover is thinnest in the northern part of the county and along the river bluffs of the Mississippi.

Because of the variable nature of the bedrock and soil, an understanding of the geologic setting is vital in determining the practicality of many land-use projects, such as waste disposal and highway construction. A thorough geological investigation of the bedrock and soil is recommended for each proposed development site. Problems in choosing sites for sewage lagoons and sanitary landfills may arise because of varying soil permeabilities and depths. Often the soil type is ideal for the project, but the amount of soil available is inadequate. Septic-tank locations must be carefully chosen to insure that enough soil cover is available for filtration to prevent effluent from entering the groundwater system directly. Land-use sites in the alluvial plains must be carefully selected to avoid pollution of the shallow groundwater table, rupture by groundwaters and damage by flooding river waters.

Mineral resources include crushed and broken stone, sand, gravel, clay and shale. Cement is manufactured from crushed limestone and river alluvium. These mineral resources are easily obtainable and are in plentiful supply. Additional growth within the county can be met by existing resources. Areas endowed with these resources should be zoned for development of mineral industries so that future demands can be met.

The surface and groundwater resources in the county are plentiful. Wells in the lowlands often produce more than 2,000 gallons per minute, and additional water supplies from surface water sources are not needed. Wells in the highlands area do not usually produce more than 20 gallons per minute, so that water supplies for other than home use, in lightly urbanized areas, must be supplemented by water from the Mississippi River. Groundwater should be tested to determine if treatment will be necessary. Water obtained from the Mississippi River requires treatment before use. Cape Girardeau County is in an area of earthquake activity, and one can expect to feel tremors on occasion.

Problems encountered with geologically oriented development in Cape Girardeau County extend beyond the county's boundaries and are found in the four adjacent counties.

This report is intended to serve as a regional appraisal of the county's geologic features, resources, and problems and is not intended to supply all the information needed for development. Proper land use will require careful on-site investigation by a geologist at each proposed development site.

Landforms and Relief

Cape Girardeau County has varied topography. The surface is generally hilly, except for a small area in the southern part of the county and in the flat Mississippi River floodplains. Relief ranges from about 50 to 100 feet in northern Cape Girardeau County, and is about 200 feet along the Mississippi River bluffs adjacent to the floodplains. Floodplains of the smaller streams are narrow, being one-third to one-half mile wide. Slopes are gentle over most of the area, except for the bluffs along the smaller streams and Mississippi River. Karst topography is present in the central portion of the county in an area extending from Oak Ridge to just south of Jackson.

Rock and Soil Formations

The bedrock of Cape Girardeau County is quite varied. Dolomite and limestone are the most commonly exposed rock. Sandstone and shale account for less than one-third of the exposed bedrock.

Western Cape Girardeau County is underlain by thin-bedded limestone, dolomite and sandstone. For the most part these rocks are thin-bedded and where exposed are quite flaggy. Soil cover is generally thin in the north, ranging between 0 to 15 feet and usually averaging less than 10 feet. Soils in the southern part are deeper, being from 15 to 30 feet thick, and in some places thickness may be as much as 50 feet. Soils are usually of a clayey to sandy-clay type. At the toes of slopes the soils are of a colluvial type, meaning a mixture of residuum and loess (a wind-blown silt).

In the eastern part of the county soils are much thicker, except for a few places along the Mississippi River and Ozark escarpment in the south. Soils thicknesses vary from 0 to 30 feet or more and on the bluffs from 0 to 10 feet. Soils in the northern part are residuum. They are usually a cherty, sandy, or silty-clay type. Those in the south are again colluvial, being a mixture of residuum and loess.

Along the Mississippi River and south of the Ozark escarpment, soils are for the most part alluvial. This alluvium is a mixture of clay, sand, gravel and silt. Thicknesses range from 0 to 120 feet. Formerly, this was the river bed of the Mississippi.

Earthquake Potential

Cape Girardeau County is in an area of earthquake activity. Several mapped faults are present, in addition to a number of collapse structures of unknown origin and the Brooks Dome structure in east-central Cape Girardeau County. Although earthquake tremors have been felt several times within the past 100 years, the area is not considered to be in danger of major earthquake activity.

Scenic Natural Resources

Caves and springs are found in the Cape Girardeau County area. Twenty-five caves have been reported, and although none of these have been commercialized, they are often visited by spelunkers, scouts, and others interested in viewing these scenic features created by the action of groundwater. There are no large springs within the county, but many small ones can be found.

Mineral Resources

Cape Girardeau County's mineral industries account for a significant part of the county's total industrial output, but because of the limited number of producers, annual dollar values are confidential. Limestone is the most important mineral resource of the county. Cement and crushed stone are the principal products of this industry. Clay and sand are produced and account for the remainder of Cape Girardeau's mineral industry.

Cement. At present there is one cement plant operating in the county. Marquette Cement Company manufactures cement from limestone and Mississippi River alluvium.

Limestone suitable for cement manufacture crops out in a belt 3 to 8 miles wide just west of the City of Cape Girardeau and extending northward to the county line, and in a small area lying northeast of the city.

Stone. In Cape Girardeau County there are three quarries producing crushed stone from limestones. These quarries are large scale operations; two are located at Cape Girardeau and one at Old Appleton. Stone is available and quarried intermittently along the Mississippi River for rip-rap.

Limestone resources suitable for production of construction aggregate and aglime are plentiful.

Clay and Shale. Three companies produce clay materials from deposits in Cape Girardeau County. Marquette Cement Company at Cape Girardeau uses river alluvium in its cement manufacturing process. Kasten Clay Products, at Jackson, manufactures pressed brick from residual clays and clay-enriched loess, and Ceramo Company, also at Jackson, utilizes the same material in its manufacture of pottery.

Additional deposits of clay-enriched loess, shale, and alluvium suitable for manufacture of structural-clay products and light-weight aggregate are present in the county.

Small, impure deposits of kaolinite, suitable for making white porcelain, are present in Cape Girardeau County. The small size of the deposits and impurities are drawbacks to any sizeable development.

Sand and Gravel. The Mississippi River constitutes the major source of sand in the county. Cape Girardeau Sand Company, at Cape Girardeau, is the major sand producer. Reserves of sand are adequate for the foreseeable future.

There is some small-scale, intermittent production of creek gravels but gravel reserves are minor.

Industrial (Silica) Sand. Industrial sand has never been produced in Cape Girardeau County; however, very large reserves are known. Many suitable sites could be developed in the St. Peter Sandstone, a north-south outcrop belt 2 to 6 miles wide, if demand for industrial silica sand increased.

Water Resources

The supply of water in Cape Girardeau County is adequate for present needs and is of such a magnitude that anticipated future needs can also be met.

Surface Water. Surface water is plentiful, but only the Mississippi River is capable of supplying the demands of a large city. The course of the Mississippi River along the eastern edge of the county makes this a readily accessible source of water for communities and industries located there. This water is of poor quality and requires treatment by a municipal treatment plant for Cape Girardeau.

Groundwater. Groundwater is produced from two geologically very distinct parts of the county: the lowlands and the highlands.

The lowlands of southern Cape Girardeau County are underlain by alluvial material. This alluvium is composed of unconsolidated clays, silts, sands, and gravels. Thicknesses vary from 0 to 120 feet. Sands and gravels commonly constitute 80 percent of this thickness. As the thickness of the alluvium varies, so does the yield capability. In optimum locations, yields in excess of 2,000 gallons per minute can be obtained.

The chemical quality of this water is good, but there is a fair amount of iron present which must be removed before it can be used for many industrial purposes. Total dissolved solids are about 350 parts per million; total hardness is about 270 parts per million. Sodium, chlorides, and sulfates are very low. Except for the iron concentrations, this water meets public health standards.

Recharge of the aquifer is accomplished by precipitation and from local streams and is of such a magnitude that depletion of water is prevented; and its over-development in the foreseeable future is thus precluded.

The aquifers of the highlands are consolidated rock formations consisting of sandstone, dolomites, and limestones. Wells can usually be developed for home use in these aquifers without problems of insufficient yields or mineralized water. These home wells generally yield from 5 to 20 gallons per minute. Depths range from 200 to 800 feet due to the dipping rock strata and are deeper in the eastern part of the county. Home wells, if improperly constructed, are vulnerable to pollution. In too many cases septic tanks are either improperly built or sites are unwisely chosen, and this compounds the hazard of pollutants reaching the home well-water supply.

Public water supplies are obtained from deeper wells that have been cased and grouted to prevent contamination by surface pollutants. The construction of the wells at Jackson is typical of those which meet public health standards. These wells, some 1,700 feet deep, have as much as 375 feet of casing which has been pressure-grouted with cement. These wells are capable of yielding in excess of 500 gallons per minute. Pumping levels range from 150 to 250 feet. Eastward and southward from Jackson, yields decline sharply and water quality declines. At the Trail of Tears State Park, a well 1,700 feet deep yields only 30 gallons per minute. At Cape Girardeau, on the campus of Southeast Missouri State University, wells 1,700 feet deep have yields of only 120 gallons per minute. An exception is number 3, which yields more than 500 gallons per minute.

The chemical quality of the water at Jackson is good, and treatment is not mandatory. Total iron is generally low, and total dissolved solids are about 300 parts per million, with total hardness about 250 parts per million. The chemical quality of the water at Cape Girardeau is poor and does not meet public health standards. In parts per million, chlorides are about 370, total dissolved solids 1,100, and total hardness 460. Fortunately for this area, waters from the Mississippi River can be used to supplement their groundwater supply. Unlike the lowlands, the highlands aquifers cannot support a major increase in groundwater utilization.

Land Use

Proper land use is a goal of the engineering geologist. To obtain the optimum use or benefits of the land, it is necessary to gain an understanding of the bedrock and soil present. Information dealing with permeability, porosity, structure, strength, and availability must be determined if the correct site is to be chosen in each particular case. Cape Girardeau County can be divided into five units for the purpose of describing the land-use limitations in each area. These units conform to those designated by Hoffman in Stout and Hoffman (1973).

Unit One - Carbonate Bedrock With Some Shale (Ca-Sh)

This unit is located in eastern Cape Girardeau County. Bedrock is composed primarily of limestones, but there are local areas of sandstone and shale along a narrow north-south band near the center of the area. Soil is a clayey silt. Thickness of the soil is less than 30 feet.

Sewage Lagoons. Satisfactory sites for sewage lagoons can be located with relative ease in this area, except where the terrain is more rugged and where soil is thin. Most problems can be overcome by choosing a proper site and using engineering-design techniques. For example, perhaps only a portion of a lagoon site is suitable, but with the addition of clay or bentonite seepage loss can be prevented. Because conditions at each proposed lagoon site will vary, an investigation should be made to determine the capabilities of each site.

Septic Tanks. Due to the varied nature of the bedrock (carbonates and shales), a detailed study is necessary for each proposed site. The success of a given septic tank will depend upon the characteristics and depth of the soils present and the density of septic-tank development. Areas that have shallow soils along the Mississippi River in the northeastern portion of the county are poorly suited for septic tanks, except perhaps for rural areas such as farms or large estates. The remaining part of unit one has sufficient soil cover to permit septic tanks to be used in lightly urbanized areas where lot sizes exceed three acres.

Sewage Treatment Plants. Sewage treatment plants can be located without much difficulty relative to geologic conditions of the receiving stream. All treatment plants should be located so that discharged effluent will enter gaining streams, which are common in this unit.

Sanitary Landfills. Sites that are acceptable for landfills are for the most part limited to areas of thick soil cover. Soils in the northeastern portion of the county are not well suited for sanitary landfills. Possibilities exist for satisfactory landfill sites in other parts of this area, but extreme caution should be used when selecting a site.

Impoundments. Most areas are suitable for lake development. Areas where carbonates and sandstones crop out may have some seepage problems, but padding with clays may help prevent leakage. In a few extreme cases more costly treatment procedures may be required.

Construction. No serious problems are anticipated in finding sites where small buildings such as houses can be built. Careful examination should be made of the bedrock and soil, however, when buildings larger than homes are to be constructed and for any buildings to be erected on a steep slope.

Unit Two - Carbonate Bedrock With Some Sandstone (Ca-Ss)

Unit Two is located in west-central Cape Girardeau County. Bedrock consists primarily of thin-bedded carbonates, with some sandstone. Soil cover varies in composition horizontally and vertically - sometimes clayey, silty, or clayey loess.

Sewage Lagoons. Suitable lagoon sites may be difficult to locate. The difficulty arises, not because of the quality of the soils, but because the quantity of soil available is often insufficient. Soils are often shallow in the northern part of this area, but they are usually thick enough in the southern portion. Often, when excavating for a shallow lagoon site, bedrock will be exposed. Another difficulty arises in karst areas because lagoons should never be located in sinkholes or in drainage fields near sinkholes.

Septic Tanks. Soil-cover thickness and type is of primary importance. In too many cases septic tanks have been located on or in the bedrock, where no filtration could take place and either surface or groundwater pollution occurred.

Sewage Treatment Plants. Few problems are anticipated in this area. Bedrock and soil are favorable to construction of these plants. Plants, however, should be located so that effluent will be discharged into a perennially flowing stream. In the case of losing streams, discharge could enter the groundwater system.

Sanitary Landfills. Sites will generally be difficult to locate because of thin soil cover. Where adequate soil cover is present, especially in the western portion of this Unit, small community landfills can be located with less danger of contamination of the groundwater supply. It is recommended that in these areas a complete geologic investigation be made at several prospective sites to determine the best one. In areas where karst is well developed, sanitary landfills should be discouraged except under extreme conditions and, in all cases, a thorough geologic investigation should be made.

Impoundments. Lakes can be developed in most parts of this area. Soil depths are adequate in the western and southern parts of the area. If bedrock is encountered while excavating at a lake site, undercutting and repacking with impermeable clays will be necessary to prevent leakage. Lakes developed in karst areas could trigger collapse and are more likely to fail than those built over competent bedrock.

Construction. Only areas within the karst region are unfavorable for the construction of large buildings. Single-family dwellings can be built almost anywhere.

Unit Three - Karst (Ca-K)

This unit is located in central Cape Girardeau County. The bedrock consists of permeable limestone. The bedrock surface is very irregular, even over short distances. Caves, sinkholes, and pinnacles are common features, known collectively as karst. A highly variable, stony, red clay soil covers the limestone bedrock. Thicknesses vary from 0 to more than 100 feet.

Sewage Lagoons. Suitable sites may be difficult to locate because of unfavorable bedrock and soil conditions. Where soils are thin, leakage to bedrock may occur and pollution of the groundwater system might easily happen. Soils in this unit are very permeable; lagoon sites may require clay padding or bentonite to prevent leaks. The use of sewage lagoons should be discouraged.

Septic Tanks. In karst or sinkhole areas, septic tanks should not be located where drainage can enter sinkholes. Drainage fields should be located on ridges, so that effluent will be filtered before entering the groundwater system.

Sewage Treatment Plants. The location of suitable discharge points may be difficult. Unless effluent is discharged into a stream with sustained flow, there may be a loss of insufficiently diluted effluent to the groundwater system.

Sanitary Landfills. Sinkholes should not be used for landfills because of the direct connection that exists between sinkholes and the groundwater system. For similar reasons, landfills should also be avoided where there are thin soils or bedrock is exposed. In general, most of this area is not suitable for sanitary-landfill development. Any area proposed for development should be investigated by a geologist.

Impoundments. This unit is suitable for small farm ponds in those areas where thick clay soils are present. These ponds could be constructed with little leakage.

Construction. Development in sinkholes or sinkhole drainage fields should be discouraged to avoid disrupting the movement of surface water toward these natural drains.

Unit Four - Intermediate-Thickness Residual Soil Over Carbonate Bedrock (Ca-I)

This unit is located in western Cape Girardeau County. Bedrock formations consist of permeable carbonates. Covering this is a stony, red clay soil. Soil thickness varies from 20 to 40 feet, and permeability varies from low to high.

Sewage Lagoons. Suitable sites for development as sewage lagoons will be difficult to locate. Because of the varying permeability and thickness of the soil cover, it will be necessary that each proposed site be carefully investigated by a geologist. Lagoons constructed in areas where thin soil or soils of high permeability are found are likely to fail if remedial measures are not taken. Leakage can be lessened by the use of impermeable clay padding or bentonite.

Septic Tanks. Because of the nature of the soil, septic tanks should only be used where the soils have moderate permeability. This will allow for proper filtration of the effluent. Septic tanks should only be used in rural settings where there will be three or more acres per tank serving as a drainage field.

Sewage Treatment Plants. Treatment-plant discharge should only be made into streams with perennial flow. The permeable nature of bedrock and soil is conducive to pollution of groundwater supplies.

Sanitary Landfills. Suitable sites will be difficult to locate. Only those areas where impermeable, thick, clay soils are present are acceptable. In some cases, the clay soil may have to be treated with bentonite or padded with impermeable clay to prevent leakage.

Impoundments. Small farm ponds may be constructed with some difficulty. Bentonite or clay padding may be necessary to prevent leakage. Large impoundments will be difficult to construct because of the permeable nature of the bedrock and soil.

Construction. Problems encountered include low wet-soil strength and variable permeability of the soil.

Unit Five - Alluvial Soils and Poorly Consolidated Clays, Shales, Sands and Gravels (Al-Tm, Al-Tc and C-S)

Unit Five is located in the southern part of Cape Girardeau County. The area is an alluvium-filled valley. This alluvium is composed of weathered loess, silt, clay, and gravel. An area of poorly consolidated clay, silt, sand, and gravel in southwestern Cape Girardeau is included with the alluvial soils because of their similarities in engineering properties. The water level is shallow and is perhaps the most important factor in land development to be considered. Surface flooding is also a very important factor in land-use development.

Sewage Lagoons. Lagoons can be successfully built if proper precautions are taken. Great care should be exercised in keeping the lagoon floor well above the water table and seeing that an adequate thickness of clay padding is left between the lagoon floor and the water-table surface. A lagoon should also be protected from damage by flood waters by using high banks around it. If borrow material is required for constructing these high banks, it should be obtained from outside the perimeter of the lagoon and not by deepening the lagoon interior.

Septic Tanks. The use of septic tanks should be restricted. In sandy areas, use should be restricted to rural settings. In clayey areas they can be used in lightly urbanized settings without danger of polluting the groundwater system.

Sewage Treatment Plants. Few Problems will be realized from treated effluent if the discharge is limited to streams with sustained flow.

Sanitary Landfills. Because of a high water table and the possibility of flooding, few sites exist for sanitary landfills. Favorable sites are those where there is a thick, clay-rich soil which can prevent leachates from leaking into the groundwater. These sites require careful selection and must be evaluated to determine the hydrologic characteristics of the alluvial-groundwater system.

Impoundments. Only small ponds or lagoon-type impoundments can be considered due to the high groundwater level. These could be built in areas of impermeable clay soils near small hills or ridges.

Construction. Problems will be encountered. Buildings with basements will probably be flooded part of the time unless the groundwater can be diverted. Settlement problems may occur where excessive or vibratory loads exist or where more than one soil type is under the foundation.

* * * For additional geologic information concerning Cape Girardeau County see these selected references: 3, 6, 7, 8, 13, 14, 15, 16, 17, 18, 20, 21.

OZARK, STONE AND TANEY COUNTIES, LAKES COUNTRY AND SOUTH CENTRAL OZARKS REGIONS

Summary

Ozark, Stone and Taney Counties have a rugged topography. The northwestern area has rolling hills, with moderately steep slopes and narrow valleys. The remaining area is dissected, producing generally more rugged terrain, with very steep slopes and narrow valleys. Floodplains of considerable size are nonexistent. The major floodplains have been covered by four large lakes created by impounding the White River and its tributary the Norfork. Soil cover is generally very thin, except on some hilltops and in valleys at the bases of hills. Many caves are well developed in the bedrock with three commercial caves now being operated and a potential for commercialization of other caves. There is little chance of earthquake activity.

The mineral resources produced in the three-county area are limited to stone, sand, and gravel. Limestone is quarried in Taney County. Sand and gravel are produced from residual cherts and alluvium in Stone County for fill material. Gravel is municipally developed in Ozark County. There is little reason to believe that these industries will be greatly expanded in the future. There are no known economical deposits of metals (zinc, lead, or iron) within the area. There are no fuel resources.

Water resources in the three-county area are adequate. Surface water is of good quality. Groundwater is of good quality and is readily available for rural, domestic, and municipal use. Home wells penetrate 100 to 800 feet. Municipal wells penetrate 1,000 to 1,800 feet and supply 350 gallons per minute. Care must be exercised in drilling a well and casing must be frequently used, especially in the upper, weathered zones, to prevent contamination.

Engineering geology for land use requires that a careful survey be taken for each project considered, whether it be an impoundment, landfill, or waste-disposal site. Soil cover is of most importance when a landfill, sewage lagoon, or lake is to be built. Adequate soils are available only on some hilltops and at the bases of some hills. It is very important that these structures be constructed so as not to allow trapped waters to percolate downward and pollute the groundwater system. Septic tanks are to be discouraged in urban areas and should only be used in rural areas where the effluent can be properly filtered.

Problems similar to those encountered in the three-county area, especially those dealing with the development of natural resources and waste disposal, are encountered in the surrounding four counties.

This report is intended to serve as an appraisal of the geologic features, resources, and problems encountered in Stone, Taney, and Ozark Counties. It is not intended to take the place of an on-site geologic investigation.

Landforms and Relief

Most of the three-county area has a very rugged topography. The northern half of Stone County and the northwestern corner of Taney County have rolling hills. The remaining area is deeply dissected by streams and as a result is very steep-sloped, except for the divides. Commonly, relief is in excess of 250 feet. Numerous bluffs are present on the outsides of meanders of major streams. Formerly, the White River flowed freely and had a well developed floodplain, but within the three-county area this has all been flooded due to the construction of several large dams and their resulting lakes.

Rock and Soil Formations

The controlling influence in determining the physiography of this three-county area has been the bedrock. Each of the two provinces has its own bedrock regimen. Bedrock in the rolling hills area is varied. Massive-bedded Mississippian limestones and cherty limestones cap ridges and high plateaus. Dolomites of Ordovician age form the low-lying areas and shores of the reservoirs. Those areas which have been deeply dissected have their ridges and highlands capped by thin to medium-bedded limestones and cherty limestones. Ordovician dolomites are exposed in low-lying areas. These limestones and dolomites are very hard and dense, and only small amounts of "weaker" strata, the shales, are present. Karst is a problem in portions of this area. Ozark County and southeastern Taney County are in an area that is subject to catastrophic collapse. Caves are well developed throughout the region. Soils are primarily residual cherts with a matrix of red and gray clays. Commonly the hillsides are strewn with residual chert. Soils are best developed and usually thickest on the divides and become thinner on the slopes. Northeastern Ozark County is covered with very thick residual soils.

Earthquake Potential

The bedrock of this region generally lies flat. Isolated faulting has occurred in a number of areas and vertical displacement has been of the magnitude of 20 to 100 feet. Several sets of jointing fractures have opened the subsurface to deep weathering and cave development. Northeastward-trending lineaments have also provided openings for circulation of water and provided avenues for deep weathering in selected areas. This region has no history of modern earthquake activity and should not be considered hazardous in this respect.

Scenic Natural Resources

Caves and springs are common in the three-county area. Two hundred-nine caves have been reported.

Commercial caves have been developed in Stone County with Marvel Cave being opened to the public in 1894 and Fairy Cave (now called Talking Rocks) and Old Spanish Cave becoming commercial much later. In Taney County, a once-commercial cave, Wonder Cave, near Reeds Spring, has been closed for a number of years. Several other caves within Stone and Taney Counties are worthy of consideration as possible commercial ventures. Careful consideration must be given to several factors to make a cave profitable. These are (1) proximity to other commercial caves; (2) proximity to major travel routes or recreation areas; (3) facilities and lighting of the cave; and (4) size and beauty. In general, a cave with a good location will fare better than a cave with an unfavorable location, even though the latter may be nicer. Any cave considered for development must be inspected by the Missouri State Mine Inspector. Yearly inspections are required to insure that safety standards are met with regard to walkway construction, bridges and lighting, and structural soundness of the cave.

Springs are numerous. Nine big springs, each with a flow greater than 200,000 gallons per day, are present. Double Spring is the largest, with a flow of 100 million gallons per day. Three springs, Althea, Blue, and Hodgson Mill, can be visited.

Mineral Resources

The mineral resources of Ozark, Stone and Taney Counties are limited. At present, production is confined to the sand, gravel, and stone industries.

Sand and Gravel. Sand and gravel production in recent years has largely come from Taney County. Most of the stream valleys in the area have potential gravel resources to meet future needs, but deposits of clean sand are harder to find. Two sites are now being operated as sources of sand and gravel in central and western Taney County. The area possesses adequate resources of these materials for local needs.

Crushed and Broken Stone. Stone produced in the three-county area comes from Taney County. Both Mississippian and Ordovician limestones and dolomites are sources of these raw materials. One quarry is being operated in western Taney County. The cherty and dolomitic Ordovician formations underlie by far the greatest portion of the area. Patches of Mississippian limestones may locally contain high-calcium stone, but it is not considered likely that the area possesses sufficient quantities of this raw material base for the manufacture of lime. Sandstone locally crops out in eastern Ozark County and may be suitable for dimension stone on a small scale. In the three-county area, there are no known fuel resources.

Lead and Zinc. In the past, small lead and zinc mines were developed in Taney and Ozark Counties. The Caulfield area in Howell County was productive, but there has been no recent activity. The deposits were small and are largely worked out, and although the possibility exists that other deposits occur underground, recent exploration has not been intensive.

Iron. Iron ore was formerly mined in Ozark County from surficial deposits. Ozark County lies at the western edge of the West Plains brown iron ore district. The iron ore was shipped to out-of-state steel plants. Near-surface deposits have now been mined out, and there is little likelihood that additional economic deposits are present.

Water Resources

Surface Water. The principal source of surface water in the three-county area is the White River. Impoundments on this river are Table Rock Lake, Lake Taneycomo, and Bull Shoals Lake. A large part of Norfork Lake (built on the North Fork of the White River) extends into Missouri. A good deal of the southern portion of the three-county area is covered by the impounded rivers. Many other small streams are in the area, but none are used as sources of water supply. These large impoundments were built primarily for power generation, flood control, and recreation. The chemical quality of these surface waters is good with all chemical constituents being well below the maximum permissible amounts allowed by U.S. Public Health Service standards.

Springs are numerous in this area. Only a few of these springs, however, are large enough to supply adequate amounts of water. There are two such springs in Stone County and seven in Ozark. Their flows range from 200,000 gallons per day at Reeds Spring in Stone County to 130 million gallons per day at Double Springs in Ozark County. Chemical characteristics of this spring water are quite similar to those of the streams.

Groundwater. Groundwater of adequate quantity and quality is plentiful. Depths necessary for a home well are dictated by the topographic setting of the well. Wells drilled on ridges can be expected to penetrate greater thicknesses of rock strata than those drilled in valleys. Depths of these wells average from 100 feet to more than 800 feet. Red-clay fillings in fractures, joints, crevices, and caverns create considerable problems. This is a problem not limited to home wells alone and has led to difficulty at Gainesville. At some of the municipal well sites, it has been physically impossible to construct a well through this weathered zone in a satisfactory manner.

Public water supply wells of municipalities and water districts range in depth from about 1,000 feet to 1,700 feet. These wells penetrate the Gunter Sandstone to achieve maximum yield from this aquifer. Deeper formations are generally not sufficiently productive to warrant deeper penetration. These wells now produce 100 to 350 gallons per minute. Water quality is good. Total dissolved solids range between 250 and 350 parts per million; total hardness between 150 and 300; and iron, sodium, chlorides, and sulfates are all low.

As elsewhere in carbonate terrains, wells are vulnerable to pollution. Properly designed structures prevent leakage and penetration into the deeper aquifers. Cave-stream systems and solution channels often provide avenues for water movement. With proper site-selection investigations, well construction, and intelligent disposal of waste materials, it should be possible to continue to produce water of good quality. Recharge capabilities at present exceed rate of withdrawal. By proper well spacing, excessive drawsowns can be avoided. Water resources in the three-county area are ample for supplying all future anticipated needs.

Land Use

In order to gain a proper understanding of what the land is best suited for, a comprehensive study of its engineering properties is necessary. The planner and developer will need to consider the bedrock and its soil as a single unit in relating geologic features to construction and development. The Ozark, Stone and Taney County area is divided into eight engineering geology units. These units are directly related to the physiography of these counties.

Unit One - Variable Soil Thickness Over Massive Carbonate Bedrock (Ca-V)

Northwestern Stone County is characterized by massive limestone bedrock with a thin soil cover. The bedrock is a firm, competent unit, unless caves and near-surface, solution-enlarged openings are extensive. The development of karst is widespread in the southeastern portion of the area. Steep slopes persist in the southeastern part of the area, while a more moderate topography with gentler slopes is characteristic in northwestern Stone County.

Sewage Lagoons. Sewage Lagoons require careful construction. Careful site selection and thorough subsurface investigation are strongly advised. The subsurface soil and bedrock contain caves, pinnacles, and solution channels. Lagoons built above one of these voids could possibly cause collapse of the bedrock roof or be the victim of collapse, with loss of sewage into the underground strata and pollution of any groundwater in these strata. Lagoons built in this unit should be lined with impermeable clays; the red clays associated with this soil can be used, but may require special sealants. Brown clays mixed with bentonite provide the most suitable liners for lagoons.

Septic Tanks. Waste disposal is an extremely difficult problem due to the rugged topography and either insufficient or inadequate overburden. Clays in this unit have been derived from weathered bedrock. Septic-tank effluent will seep rapidly through this clay soil, thus reaching groundwater sources. As a result of this high permeability, the effluent will not be properly filtered. These relatively untreated waters can enter weathered joints and bedding planes in the bedrock and move laterally and vertically for long distances from their original points of discharge. Use of septic tanks should be restricted to farms to avoid concentration of effluent in the soil and possible groundwater contamination.

Sewage Treatment Plants. Sewage-treatment-plant effluent can be safely discharged in a few areas where plentiful surface water is available for dilution. However, many receiving streams lose surface flow to the subsurface. Thus they must be thoroughly explored to determine the extent of this possible hazard to groundwater supplies.

Sanitary Landfills. Sanitary landfills should not be built without prior geologic investigation. The practice of using sinkholes and abandoned mine shafts as waste disposal dumps should be strongly discouraged. Inadequate amounts of proper fill material hinder operations over much of this area. Sites can be located where bedrock has contributed to development of more impermeable soils.

Impoundments. The development of lakes in this area is favorable because of good stream flow. While there is relatively little water loss to bedrock if precautions are taken leakage into bedrock and soil is a likely hazard. Many sites have either inadequate or unsuitable borrow material for dams.

Construction. Construction poses a problem only in those cases where a lot of fill material is needed such as in construction of large buildings or roads. Red-clay soils perform poorly in compacted fills.

Unit Two - Shallow Residual Soil Over Carbonate Bedrock (Ca-S)

This unit is located in portions of all three counties. The bedrock in this unit consists mainly of medium-bedded dolomites. Maximum soil cover is seldom more than 15 feet and is usually much thinner and in many cases nonexistent. The dolomite is characterized by persistent horizontal parting planes and vertical fractures.

Sewage Lagoons. Sewage-lagoon construction is difficult because of steep hillsides and little soil cover over bedrock. Possible lagoon sites lie at the bases of hills where soils are somewhat thicker, or on tops of slopes where there is sufficient soil depth. Many of the small creek channels that cross this unit could be used for lagoon sites if diversion channels were constructed for the stream flow. However, soils are usually gravelly. Clay materials which can be found in the creek bottoms are suitable to prevent waste fluids from leaking out of the lagoon. Lagoon sites should not be excavated into bedrock. Loss of pollutants will occur, especially horizontally into the cut slope by way of fractures and joints in the bedrock. At some sites, bedrock excavation can be accomplished if sealing is possible.

Septic Tanks. Waste disposal must be carefully planned. Steep slopes with thin soil cover are not well suited to septic tank usage since there is too little room for septic tank effluent to disperse. As a result, the effluent usually comes to the surface and causes a pollution problem. If septic tanks are to be used, they should not be used in highly populated areas, but on farms or in sparsely populated areas.

Sewage Treatment Plants. Treatment plant effluent in most cases will be sufficiently diluted with surface water. Most waterways only suffer minor losses to the bedrock, usually when caves or sinkholes are nearby.

Sanitary Landfills. These sites are hard to find because of the relatively thin soil overburden and steep slopes. The major factor is the availability of soil for landfill and clay for lining the landfill site to prevent percolation of polluted surface waters. Sufficient soil cover is usually available at the bases of hills, or in some cases at the tops of hills. Exploration of soil depth should be carried out at each proposed landfill site to check on the amount and type of soil present.

Impoundments. Lakes can be constructed if extreme care is given to location, design, and remedial measures. There are, however, many regions where it is foolish to consider water impoundments, since there would be leakage into the permeable bedrock.

Construction. Foundation problems are usually minor in this unit, but those developments where much excavation is required and where bedrock would be encountered will require careful planning. Little soil is available for construction where much fill is needed.

Unit Three - Intermediate-Thickness Residual Soil Over Carbonate Bedrock (Ca-I)

This unit comprises portions of northeastern, central and southern Ozark County. Bedrock consist of dolomite and cherty dolomite. Soil cover is generally a cherty-clay type. Thicknesses usually vary from 20 to 40 feet, but may be less locally. On-site investigation will be necessary to determine the exact depth to bedrock at each proposed site.

Sewage Lagoons. Suitable sites for development of sewage lagoons can be located without great difficulty. If bedrock is encountered during excavation, remedial measures will be necessary. The soil cover present in this unit is quite permeable and clay padding or a bentonite-and-clay-mixture sealant will be necessary to insure that leakage is kept to a minimum.

Septic Tanks. The use of septic tanks should be restricted to rural areas where soil thickness is greater than 20 feet and septic tank density is low (generally one tank per three acres). Septic tanks constructed where thin soil cover is present will cause pollution problems because of unfiltered effluent surfacing.

Sewage Treatment Plants. Because of the permeable nature of both bedrock and soil, most of the streams in this unit have surface flow lost by seepage into groundwater supplies. Treatment-plant effluent should not be discharged within this area because of the danger of polluting groundwater resources.

Sanitary Landfills. Sites suitable for development as sanitary landfills can be located without too much difficulty. However, remedial measures will be necessary in order to prevent leachates from leaking into bedrock. Subsurface exploration prior to site selection will be necessary and at times somewhat costly.

Impoundments. Because of the permeable bedrock and soil, remedial measures will be necessary to insure success for small impoundments built in this area. Larger impoundments may be impossible to seal effectively and may also fail because of catastrophic collapse.

Construction. Problems encountered include possible catastrophic collapse.

Unit Four - Thick Residual Soil Over Carbonate Bedrock (Ca-T)

This unit is located in portions of northeastern Ozark County. Bedrock consists of dolomite and cherty dolomite. Soil cover is thick (40-100 feet) and is generally a stony-clay type.

Sewage Lagoons. Suitable sewage lagoon sites will be difficult to locate. The soil and bedrock have high permeability and leakage of effluent from the lagoon into the groundwater system is possible. Remedial measures such as using bentonite and impermeable clays can be used in most cases to prevent this leakage.

Septic Tanks. The use of septic tanks should be restricted. Areas that are sparsely populated are best suited for this type of sewage treatment.

Sewage Treatment Plants. The high permeability of the soil and bedrock formations has resulted in a number of losing streams. Effluent could easily enter the groundwater system and cause pollution problems if discharged in an unsuitable location along a stream valley.

Sanitary Landfills. Sites suitable for development as sanitary landfills can be located without great difficulty. Proposed sites will require that test pits, and perhaps borings, be dug to determine site suitability. If the soil present is permeable, it may be possible at some sites to correct this problem by using bentonite mixed with clay to seal the floor and walls of the landfill site. However, this is a costly procedure. Collection of leachates by using a small lagoon may also be necessary.

Impoundments. The same problems encountered with locating a suitable lagoon site will also be faced here. The success of a small pond or lake will depend largely on the permeability of the soil found at each proposed site.

Construction. Locally, problems include karst conditions, losing streams, variable strength of soils and possible catastrophic collapse of bedrock.

Unit Five - Karst (Ca-K)

This unit is located in portions of eastern Ozark County and central Stone County. Bedrock consists of very permeable dolomite. Karst features such as caves and sinkholes are well developed throughout the area and present a considerable challenge to successful land development. Soil depths vary from 0 to 100 feet and the composition is generally a very cherty clay.

Sewage Lagoons. Sewage lagoons should not be used in this area. The high permeability of both soil and rock will prevent the lagoon from retaining effluent. As a result of this, contamination of the area's groundwater resources is likely to occur. Contamination can also occur as a result of catastrophic collapse of bedrock supporting the lagoon structure.

Septic Tanks. Many problems will be encountered in locating suitable sites for septic tanks. Only those areas where thick clay-rich soils are present should be considered acceptable. Septic-tank use, in most cases, should be restricted to rural or farm settings only, where three acres or more are available as a filtration field for each tank.

Sewage Treatment Plants. Because of the highly permeable nature of the soil and bedrock, discharge should be limited to streams with continuous flow. Many streams lose surface flow to groundwater supplies.

Sanitary Landfills. Suitable sites for sanitary landfills will be difficult to locate. Gullies and small, tight valleys with deeper soils are possible sites. Remedial measures, such as using a bentonite additive or clay padding for the lagoon floor, may be necessary to insure that leachates will not leak into the soil and bedrock. Sinkholes should not be used as sanitary landfills because of the direct connection they have with the groundwater system. Whatever the setting, subsurface exploration will be necessary before final decisions can be made.

Impoundments. Suitable sites will be difficult to locate. Small farm ponds may be constructed, but remedial measures will probably be necessary. Bentonite and/or impermeable clays can usually be used successfully to control leakage. There is some danger of catastrophic collapse with larger impoundments, because of the increased loss of strength due to wetting of subsoil. Careful investigation will be necessary to determine the strength of bedrock at the various proposed sites.

Construction. Problems encountered include catastrophic collapse, variable soil depth to bedrock, and remnant bedrock blocks (enclosed within soil).

Unit Six - Shallow Residual Soil Over Sandstone Bedrock (SS-S) .

This unit is located in a small portion of northeastern Ozark County. The bedrock consists of massive sandstone. The soil cover is 0-20 feet thick and consists of red sandy clay mixed with sandstone boulders and cobbles. Permeabilities of both soil and bedrock are high.

Sewage Lagoons. Suitable sites for sewage lagoons will be difficult to locate. Remedial measures such as impermeable clay padding will be necessary to insure that the lagoon will not leak effluent into the sandstone bedrock. If bedrock is encountered during excavation, it will be necessary to over-excavate and seal with packed clay.

Septic Tanks. Septic tanks should be used sparingly. Only in those areas where deeper (20 feet) soil cover is present can they be utilized. Septic tank density should not be greater than one tank per three acres. Areas with thin soil cover or high septic tank density will have groundwater-pollution problems.

Sewage Treatment Plants. There are few suitable areas within this unit. Effluent discharged could easily permeate into the soil or exposed bedrock over much of the area and cause pollution.

Sanitary Landfills. Suitable sites for development as sanitary landfills can be located with some difficulty. Thorough exploration and remedial measures will be necessary in each case, but these will vary with the size of landfill and the type of soil and bedrock present.

Impoundments. Suitable sites will be very difficult to locate. High rock and soil permeability will make it difficult to retain water in a pond or lake.

Construction. Problems encountered include occasional sinkhole collapse and moderate to severe hillslope erosion.

Unit Seven - Intermediate-Thickness Residual Soil Over Sandstone Bedrock (SS-I)

This unit is located in northeastern Ozark County. Bedrock consists of massive sandstone and dolomitic sandstone. Overlying these bedrock are soils which usually have a thickness of 20 to 40 feet, but locally the thickness may vary. The soil is primarily a silty or sandy clay.

Sewage Lagoons. Suitable sites will be difficult to locate. Remedial measures will usually be necessary to insure that effluent will not leak into soil and bedrock. Compacted clay or bentonite can usually be used successfully to prevent leakage.

Septic Tanks. Septic tanks can be used successfully in those areas where deeper (30 to 40 feet) soil cover is present. Septic-tank density should not exceed one tank per three acres.

Sewage Treatment Plants. As with unit four, suitable sites will be difficult to locate. Effluent lost to bedrock will usually cause some groundwater pollution. Discharge points must be chosen carefully to prevent such pollution.

Sanitary Landfills. Sites suitable for development may be difficult to locate because of the high permeability of bedrock and soil. In most cases, remedial measures will be necessary to insure that leachates do not leak out of the landfill. Exploration will be necessary to determine the best site.

Impoundments. The same problems encountered with selecting a site for a successful sewage lagoon will be faced here.

Construction. Problems encountered include catastrophic sinkhole collapse and moderate to severe hillslope erosion.

Unit Eight - Thick Residual Soil Over Sandstone Bedrock (SS-T)

This unit is located in portions of northeastern Ozark County. Bedrock consists of sandstone and dolomitic sandstone. A thick, silty clay or sandy clay overlies bedrock. Thicknesses vary from 40 to 100 feet, but may vary locally.

Sewage Lagoons. The ease with which sites suitable for sewage lagoons can be located will depend largely on the permeability of the soil cover. Some areas within this unit have a silty-clay soil that has sufficient impermeability to permit building of a lagoon. Other areas will have a very permeable, sandy clay soil and therefore be unsuitable for development. Careful geologic investigation will be necessary to determine soil permeability at each proposed site.

Septic Tanks. Septic tanks can be used in most cases within this unit. Because soil permeability is often high, it is recommended that the use of septic tanks be limited to rural settings.

Sewage Treatment Plants. Suitable sites can be located for effluent-discharge points. Because of the very permeable sandstone bedrock, it is recommended that discharge be limited to streams with perennial flow.

Sanitary Landfills. Suitable sites may be difficult to locate because of variable permeability of the soil. In many cases remedial measures, such as using bentonite, will be necessary to prevent leakage of leachates. Exploration pits and borings, coupled with soil testing, may be necessary prior to site evaluation.

Impoundments. Problems are the same as those encountered in locating sewage lagoon sites.

Construction. Problems encountered include possible catastrophic sinkhole collapse, moderate to severe hillslope stability and variable soil permeability.

* * * For additional geologic information concerning Ozark, Stone and Taney Counties see these selected references: 1, 2, 3, 6, 7, 8, 13, 14, 15, 16, 17, 18, 19, 20, 21.

HOWELL COUNTY, SOUTH CENTRAL OZARK REGION

Summary

The topography of Howell County is both rugged and varied. Relief commonly ranges from 75 to 300 feet, with greatest relief along the northern, eastern and western boundaries. Sinkholes are very common in the karst regions of the county. The floodplains of major streams are generally narrow and rarely exceed 1/3 mile.

Bedrock units consist primarily of dolomite, cherty dolomite and sandstone with minor amounts of shale. Soil cover consists of cherty clay and sandy clay. Alluvial soil is found in valleys of the major streams. Thickness of the soil varies from 20 to 100 feet, with the thicker soils in northern and central Howell County.

Howell County is not considered to be in danger of earthquakes.

There are a number of springs and caves in Howell County. Big Spring near Willow Springs has the greatest flow of any of the county's springs, with a flow of 910,000 gallons per day.

Mineral production in Howell County is currently limited to stone, sand and gravel. Iron, lead and zinc occurrences are known in the area but are not profitable to mine.

Water resources are plentiful and a three - to five-fold increase in groundwater use could be tolerated. Public wells are often over 850 feet deep and need to be cased to prevent clay and surface pollutants from entering. These wells yield between 80 and 500 gallons per minute.

Proper land use (waste disposal and construction) require detailed geologic investigations at proposed development sites. Eight engineering-geology units are in Howell County and each have different requirements for successful development.

Problems similar to those encountered in Howell County, especially those dealing with the development of natural resources and waste disposal, are encountered in the surrounding five counties.

This report is intended to serve as an appraisal of the geologic features, resources and problems in Howell County. It is not intended to take the place of on-site geologic investigation and evaluation.

Landforms and Relief

Howell County has rugged topography. Along the county's northern and western boundaries and along portions of its eastern boundary the dominant landform is a highly dissected plateau. Here relief is greatest and in general varies from 100 to 300 feet. In the central portion of the county and along portions of its eastern boundary the dominant landform consists of isolated rolling plains. In this region relief is not quite as great and in general varies from 75 to 100 feet. The floodplains and valleys of the county's principal streams, the Eleven Point River, Spring River and North Fork River vary from as little as 1/10 mile to, usually, no more than 1/3 mile. Sinkhole topography is common in central Howell County.

Rock and Soil Formations

Bedrock formations are limited to dolomite, cherty dolomite, sandstone and minor amounts of shale. Locally, overlying these dolomite units are unconsolidated clay and sand deposits. The soils developed over these units are directly related to the parent material from which they were derived by weathering. These soil types are generally cherty clay and sandy clay. Alluvial soils are in the valleys of the major streams. Sandy clay soils are found in portions of northern and central Howell County. Soil depth is usually 40 to 100 feet thick, but may be more or less, depending on local conditions. Soil thicknesses in the remainder of the county vary from 20 to 40 feet, but again will vary with local conditions.

Earthquake Potential

The bedrock units in Howell County are, for the most part, flatlying. There is a very slight (1^{o}) dip to the south. There are no mapped faults or folds within the county; however, the Alice Mine fault structure in nearby Ozark County may extend into Howell County. Additional geologic mapping is necessary to determine the extent of this fault and the possible presence of other faults. The area is not considered to be in danger of earthquake activity.

Scenic Natural Features

There are a number of springs and caves in Howell County that are of geologic and scenic interest. Fifteen caves are reported but none are large enough to commercialize. Many springs can be found scattered about the county. Big Spring has a flow of 910,000 gallons per day. Blowing

Spring near Mountain View has an average flow of 630,000 gallons per day and Flat Spring, also near Mountain View, has a flow of 200,000 gallons per day. The flow of most of the area's small springs is less than a few thousand gallons per day. West Plains karst recharges Mammoth Spring in Arkansas.

Mineral Resources

Mineral production in Howell County is restricted to sand, gravel and stone.

Iron Ore. The West Plains brown iron ore district includes all of Howell County and adjoining areas. In the past, Howell County was the leading producer of brown iron ore in the state, with production reported from 23 mines. The ore was shipped out of state, for use as blast furnace feed. Peak production was reached in 1957.

A prominent magnetic anomaly near the Howell-Oregon County line has been penetrated by several exploratory drill holes but to date there have been no indications of buried iron deposits.

Lead and Zinc. The Alice Mine area in Ozark County near the Howell-Ozark County line was discussed in the section on Ozark, Stone and Taney Counties.

Stone. Crushed and broken stone are produced from dolomite in the West Plains area. Dolomite is the principal reserve for aggregates, asphalt, road metal and aglime, but thick residuum over much of the area requires careful site selection and some exploration.

A few limestone outliers are known, but their potential has not been fully explored.

Sandstone units within the county are a potential source of dimension stone.

Sand and Gravel. Gravel for paving, bituminous surfacing, road metal, ready-mix concrete, and fill is produced mainly from stream deposits. Sand is present in areas where streams drain across sandstone outcrops. Most streams have the potential for producing large amounts of gravel but production is expected to remain relatively static.

Water Resources

Water resources in Howell County are primarily limited to groundwater. The only surface water source of any significance is the Eleven Point River, which drains the northern part of the county. In fact, many of the stream valleys in this area carry no water except immediately after heavy rains, since sinkholes and other solution phenomena act as "drains" to divert the surface water underground. Streams which do maintain a year-round flow do so by water diverted from groundwater to seeps and springs.

Thick residual deposits, coupled with widespread solution activity in the bedrock, make this area hydrologically complex. Because of the extremely permeable residual material and the "open" nature of the bedrock (in some instances to great depths), response of the groundwater reservoir to rainfall is extremely rapid. Observation wells located at Noblett Lake, in northern Howell County, and at West Plains indicate a time lag of only a few hours after it rains before water levels in the well start to rise. One public water-supply well in West Plains, which has over 800 feet of pressure-grouted casing, has been known to yield turbid water shortly after heavy rains. This would indicate rapid movement of recharge water to depths in excess of the casing depth of 800 feet.

Extreme care should be exercised in construction of both domestic and public supply wells in this county. Casing should be set deep enough to exclude all mud seams and other solution phenomena from the well. The casing should be grouted (cemented) to effect a water-tight seal against shallow groundwater, surface water and other possible pollutants.

In some instances casing depths for public water-supply wells may be in excess of 900 feet. In most instances, however, casing depths for this type of well have averaged approximately 500 feet, with total drilled depths ranging between 851 and 2,692 feet.

Yields of the public water supply wells range between 80 gpm and 500 gpm, with deeper wells having the higher yields. Almost all of the high-yield wells are completed in highly permeable dolomite at an average depth of approximately 1,500 feet.

Domestic wells in the area often have depths ranging between 350 feet and 550 feet. Casing depths for these wells should range from 125 feet to 200 feet.

With properly constructed wells, groundwater quality is quite good. Total dissolved solids range between 270 to 320 parts per million and chlorides are usually less than 10 parts per million. Naturally occurring nitrate levels are virtually nil.

Because of the rapid recharge of groundwater supplies in this county, a three - to five-fold increase in water use could easily be tolerated.

Land Use

Proper land use in Howell County requires detailed geologic investigation. Bedrock and soil conditions are quite variable. Eight of the engineering geology bedrock-soil units designated by Hoffman in Stout and Hoffman (1973) are present in the county.

Unit One - Karst (Ca-K)

This unit is in portions of northeastern Howell County. Bedrock consists of very permeable dolomite. Karst features such as caves and sinkholes are well developed throughout the area and present a considerable challenge to successful land development. Soil varies from 0 to 100 feet thick and generally the composition is a very cherty clay.

Sewage Lagoons. Sewage lagoons should not be used in this area. The high permeability of both soil and rock prevent lagoons from retaining effluent. As a result, contamination of the area's groundwater resources is likely to occur. Contamination can also occur as a result of a catastrophic collapse of bedrock supporting a lagoon structure.

Septic Tanks. Many problems are encountered in locating sites suitable for septic-tank development. Only those areas where thick, clay-rich soils are present should be considered. Septic-tank use in most cases should be restricted to rural or farm settings, where three or more acres are available as a filtration field for each tank.

Sewage Treatment Plants. Treatment plants should not be used in this unit, except in those areas where effluent can be safely discharged without danger of polluting the groundwater. Because of the highly permeable nature of the soil and bedrock, discharge should be limited to streams with continuous flow.

Sanitary Landfills. Sites suitable for sanitary landfills are difficult to locate. Gullies and small, tight valleys with deeper soils are usually best. Remedial measures such as using a bentonite additive or clay padding for the lagoon floor are necessary to insure that leachates will not leak into the soil and bedrock. Sinkholes should not be used as sanitary landfills because of the direct connection they have with the groundwater system.

Impoundments. Suitable sites are difficult to locate. Small farm ponds may be constructed, but remedial measures will probably be necessary. Bentonite or impermeable clays can usually be used successfully to control leakage. There is some danger of a catastrophic collapse with larger impoundments because of the increased load placed on the bedrock. Careful investigation is necessary to determine the strength of bedrock at all proposed sites.

Construction. Problems include catastrophic collapse, variable soil depth to bedrock, and remnant bedrock blocks (enclosed within soil).

Unit Two - Intermediate-Thickness Residual Soil Over Carbonate Bedrock (Ca-I)

This unit is in portions of northeastern, central and southern Howell County. Bedrock consists of dolomite and cherty dolomite and soil cover is generally a cherty-clay type. Thicknesses usually vary from 20 to 40 feet, but may be thinner locally. On-site investigation is necessary to determine the exact depth to bedrock at each proposed site.

Sewage Lagoons. Sites suitable for development as sewage lagoons can be located without great difficulty. If bedrock is encountered during excavation, remedial measures will be necessary. The soil cover in this unit is quite permeable, and clay padding or a bentonite and clay mixture will be necessary to keep leakage to a minimum.

Septic Tanks. Septic tanks should be restricted to rural areas where soil is more than 20 feet thick and septic tank density is low (generally one tank per three acres). This will be necessary to insure proper filtration of the sewage effluent. Septic tanks constructed where the soil cover is thin will cause pollution problems because of unfiltered effluent surfacing.

Sewage Treatment Plants. Because of the permeable nature of both bedrock and soil, most of the streams in this unit are losing. Treatment plant effluent should not be discharged into these streams because of the danger of polluting groundwater resources.

Sanitary Landfills. Sites suitable for development as sanitary landfills can be located without too much difficulty. Remedial measures are necessary to prevent leachates from leaking into bedrock. If bedrock is encountered during construction, additional bedrock will have to be excavated from the site and replaced with a packed-clay pad.

Impoundments. Because of the permeable bedrock and soil, remedial measures are necessary to insure the success of small impoundments built in this unit. Larger impoundments may be impossible to seal effectively and may also fail because of catastrophic collapse.

Construction. Problems include possible catastrophic collapse.

Unit Three - Thick Residual Soil Over Carbonate Bedrock (Ca-T)

This unit is in portions of northern, central and southern Howell County. Bedrock consists of dolomite and cherty dolomite. Soil cover is thick (40-100 feet) and is generally a stony-clay type.

Sewage Lagoons. Suitable sewage lagoon sites are difficult to locate. The soil and bedrock are highly permeable, and leakage of effluent from the lagoon into the groundwater system is likely. Remedial measures such as using bentonite and impermeable clays can be employed in most cases to prevent this leakage.

Septic Tanks. The use of septic tanks should be restricted. Areas that are sparsely populated are best suited for this type of sewage treatment.

Sewage Treatment Plants. Most areas within this unit are unsuitable for this type of development. The high permeability of the soil and bedrock formations has resulted in a number of losing streams. Treated effluent can easily enter the groundwater system and cause pollution problems.

Sanitary Landfills. Sites suitable for development as sanitary landfills can be easily located. Test pits should be dug at all proposed sites to determine the depth to bedrock. If the clay soil is too permeable, it may be possible to use bentonite mixed with clay to seal the floor and walls of the landfill site.

Impoundments. The same problems encountered in locating a suitable lagoon site will also be faced in finding a site for any impoundment. The success of a small pond or lake will depend largely on the permeability of the soil.

Construction. Problems include karst conditions, losing streams, variable strength of soils and possible catastrophic collapse of bedrock.

Unit Four - Shallow Residual Soil Over Sandstone Bedrock (SS-S)

This unit is in a small portion of northwestern Howell County. The bedrock consists of massive sandstone. The soil cover is from 0 to 20 feet thick and consists of red, sandy clay mixed with sandstone boulders and cobbles. Permeabilities of both soil and bedrock are high.

Sewage Lagoons. Sites suitable for sewage lagoons will be difficult to locate. Remedial measures such as impermeable clay padding will be necessary to insure that the lagoon will not leak effluent into the sandstone bedrock. If bedrock is encountered during excavation, it will be necessary to overexcavate and seal with packed clay.

Septic Tanks. Septic tanks should be used sparingly, and only in those areas where there is deep soil cover. Septic tank density should not be greater than one tank on every three acres. Areas with thin soil cover or high septic tank density will have groundwater pollution problems.

Sewage Treatment Plants. There are no suitable areas for treatment plants within this unit. Any effluent discharged would soon permeate the soil or exposed bedrock and cause pollution problems.

Sanitary Landfills. Sites suitable for development as sanitary landfills are difficult to locate. Remedial measures, necessary in each case, will vary with the size of the landfill and the available soil cover.

Impoundments. Suitable sites are very difficult to locate. High permeability of the rocks and soils make water retention in a pond or lake difficult

Construction. Problems include occasional sinkhole collapse and moderate to severe hillslope erosion.

Unit Five - Intermediate-Thickness Residual Soil Over Sandstone Bedrock (SS-I)

This unit is in west-central Howell County. Bedrock consists of massive sandstone and dolomitic sandstone. Overlying the bedrock are soils which are usually from 20 to 40 feet thick. Locally, the thickness may vary. The soil is primarily a silty or sandy clay.

Sewage Lagoons. Suitable sites are difficult to locate. Remedial measures are usually necessary to insure that effluent will not leak into the soil and bedrock. Packed clays or bentonite are usually successful in preventing leakage.

Septic Tanks. Septic tanks are successful where thick (30 to 40 feet) soil cover is present. Septic tank density should not exceed one tank on each 3 acres.

Sewage Treatment Plants. As with unit four, suitable sites are difficult to locate. Effluent lost to bedrock will usually cause some groundwater pollution problems so discharge points must be carefully chosen to avoid such pollution.

Sanitary Landfills. Sites suitable for development are difficult to locate because of the highly permeable bedrock and soil. In most cases, remedial measures are necessary to insure that leachates do not leak out of the landfill.

Impoundments. The same problems encountered when selecting a lagoon site will be faced here.

Construction. Problems include catastrophic sinkhole collapse and moderate to severe hillslope erosion.

Unit Six - Thick Residual Soil Over Sandstone Bedrock (SS-T)

This unit is in portions of northern Howell County. Bedrock consists of sandstone and dolomitic sandstone. A thick, silty clay or sandy clay overlies the bedrock in thicknesses that vary from 40 to 100 feet.

Sewage Lagoons. The ease with which sites suitable for sewage lagoons can be located will depend largely on the permeability of the soil cover. Some areas have a silty-clay soil that is sufficiently impermeable but other areas have a very permeable, sandy-clay soil that would not be suitable for development. Careful geologic investigation is necessary at each proposed site to determine soil permeability.

Septic Tanks. In most cases septic tanks can be used within this unit. Because soil permeability is often high, it is recommended that the use of septic tanks be limited to rural settings.

Sewage Treatment Plants. Suitable sites can be located for effluent-discharge points but because of the very permeable sandstone bedrock, it is recommended that discharge be limited to streams with perennial flow.

Sanitary Landfills. Suitable sites are difficult to locate because of the variable soil permeability. In many cases, remedial measures such as using bentonite will be necessary to prevent leakage of leachates. Exploration pits and borings, coupled with soil testing, may be necessary.

Impoundments. Problems are the same as those encountered in locating lagoon sites.

Construction. Problems include possible catastrophic sinkhole collapse, moderate to severe hillslope stability and variable soil permeability.

Unit Seven - Very Thick Residual Soil (Re)

This unit is in the extreme northeastern corner of Howell County. Bedrock is covered by very thick residual soil which consists primarily of stony, red clay that often contains "floating" bedrock blocks. Soil is usually more than 100 feet thick.

Sewage Lagoons. Sites suitable for sewage lagoons are difficult to find. Because of the moderate to high permeability of the soil, it is necessary to pad lagoon sites with compacted clays. If gravel beds are encountered during excavation, it is necessary to overexcavate and repack with impermeable clay. Where a lagoon is located in a creek valley it is recommended that the floor of the lagoon be kept above the groundwater level.

Septic Tanks. The success of any septic tank in this unit will depend largely on the amount of clay in the soil. Because of the varying soil permeability, it is recommended that septic tank use be restricted to rural settings.

Sewage Treatment Plants. There are many losing streams in this unit because of the permeable nature of the soil. It is recommended that sewage treatment plant effluent not be discharged within this unit because of potential pollution of the groundwater.

Sanitary Landfills. Because of the permeable nature of the soil, a geologic investigation should be made before a decision is made on the suitability of any proposed site. In some cases it may be necessary to pad the landfill site with impermeable clays to prevent leakage of leachates.

Impoundments. Problems include those encountered when building a sewage lagoon.

Construction. Problems include leakage from lagoons and landfills plus false bedrock surfaces caused by "floating" bedrock blocks.

* * * For additional geologic information concerning Howell County see these selected references: 1, 2, 3, 6, 7, 8, 13, 14, 15, 16, 17, 18, 20, 21.

BUTLER, DUNKLIN, MISSISSIPPI, NEW MADRID, PEMISCOT,
RIPLEY, SCOTT AND STODDARD COUNTIES,
OZARK FOOTHILLS AND BOOTHEEL REGIONS

Summary

The topography of Butler, Dunklin, Mississippi, New Madrid, Pemiscot, Ripley, Scott and Stoddard Counties is varied. Rugged hills and low, flat floodplains are present. The major streams draining the area are the Mississippi, Black, St. Francis and Current Rivers.

The bedrock units include cherty and shaly dolomite, sandstone, clay and shale. Surficial materials consist of residuum and alluvium. Thicknesses vary but the surficial materials in the eastern portion of the area are thickest.

The eight-county area is within an active earthquake region and occasional tremors can be expected.

Several mineral resources are produced in this region, including stone, sand, gravel, and clay. Stone is used for rip-rap, aglime, and construction aggregates. Sand and gravel are produced for construction aggregates and road material. Clay is produced principally for lightweight aggregates, absorbents, and brick manufacture.

Water resources are plentiful. Both surface water and ground water are being utilized. A many-fold increase in water demand can be adequately met.

Similar land conditions and development limitations can be found in the five counties adjacent to this study area. This report is not intended to provide all the information needed for geologically oriented development in this region. It is intended to serve as an appraisal only and cannot take the place of actual on-site investigation, which is recommended for any future land-development project.

Landforms and Relief

The topography of this eight-county region is diverse. In the western part of the area there is a highly dissected plateau and relief is commonly 200 feet. East of this plateau and to the south is a broad, flat alluvial floodplain. A high, ridge-like area where relief is often as much as 150 feet separates this floodplain into eastern and western parts. In Ripley and northwestern Butler Counties the valleys are narrow and floodplains are seldom more than ½-mile wide.

Rock and Soil Formations

Bedrock units in the western portion consist of thick, cherty and shaly dolomite and sandstone. The bedrock in the Crowleys Ridge area is primarily poorly consolidated sandstone and clay. East of Crowleys Ridge alluvial deposits are present covering thick, poorly indurated sediments. This alluvium was deposited by the Mississippi and Ohio Rivers as they changed courses over a period of time. The soil cover present over the sandstone and dolomite bedrock is generally a silty-clay residuum. Thickness of the residuum varies from 20 to 100 feet.

Earthquake Potential

Bedrock units within the Bootheel area are gently dipping. The Pascola arch is the major structural feature. The arch extends from the center of Butler County southeast through Dunklin and Pemiscot Counties into Tennessee. The crest of the arch has long since been eroded and the arch is now only a subsurface feature. There are several mapped faults north and west of Sikeston. Displacement at these faults ranges from 30 to 400 feet. The Bootheel area lies within the recently active New Madrid fault zone and thus is in an area of potential earthquake activity.

Scenic Natural Resources

Several caves and springs are in this area. A total of 12 caves are reported. Ripley County leads with four caves. Butler and Stoddard Counties have three each and Scott has two.

Keener Spring near Keener Station in Butler County has a daily discharge of about 13 million gallons per day and King Bee Spring near Flatwoods in Ripley County has a discharge of about 2 million gallons per day.

Mineral Resources

Known mineral resources of the "Bootheel" region are stone, sand and gravel, and clay.

Stone. Present stone production for the area is from Scott County. Uses are principally for aggregates, aglime and rip-rap. Stone resources are not well distributed, with the best resources in Scott County and material of lesser quality in Stoddard, Butler, and Ripley Counties.

Sand and Gravel. Sand and gravel production is extensive and comes from Crowleys Ridge, dredges along the Mississippi River, and stream deposits in Ripley and Butler Counties. Resources are large but not well distributed. Principal uses are in construction.

Clay. Deposits are present along Crowleys Ridge and as scattered outliers in Butler County. Principal use is for absorbents, with minor production for brick manufacture. Resources of material suitable for absorbents are large, but material suitable for brick manufacture is restricted to small deposits.

Oil and Gas. The possibility of oil and gas occurrence in the bootheel area depends upon the presence of source rocks and suitable reserviors for accumulation. Present geologic knowledge of the area is not encouraging.

Water Resources

Water is plentiful, and industrial and population increases can be many-fold without the water resources becoming a limiting factor. Only Poplar Bluff uses surface water; all other community, industrial and rural usage is from groundwater sources.

Surface Water. The major stream is the Mississippi River. The magnitude of its flow is so enormous that its volume of water will be adequate even with a hundred-fold increase in water consumption. The lesser rivers of the area are Whitewater, Castor, St. Francis, Black and the Current. Wappapello Reservoir, to some degree, regulates the flow of the St. Francis River. To some extent the flow of Black River is regulated by Clearwater Reservoir. A surplus of surface water over the land surface has been lessened considerably by a system of drainage canals. East and southeast of Crowleys Ridge these small canals drain to a lateral system which runs diagonally south-southwest from mid-New Madrid County, across a portion of Pemiscot County and the southeastern corner of Dunklin County, and into Arkansas. These canals carry a large volume of water. If needed, it is conceivable that they could be suppliers of surface water.

Ground Water. In the hill portions of Ripley and Butler Counties ground water is obtained from Ordovician- and Cambrian-age carbonates. These wells range from several hundred feet in depth for home use to more than 1,000 feet for water needs of municipalities and water districts. Red clay in pockets in the bedrock is a problem in constructing some water wells, since casing must be deep enough to exclude this red mud. Yield expectations for the deep wells are 200 to 500 gallons per minute. The quality of this water is very good.

Large volumes of ground water can be obtained in the lowlands of southeastern Missouri. (References made to Crowleys Ridge also include the Bloomfield Hills and the Benton Hills Ridge.) The lowlands to the west and northwest of Crowleys Ridge have alluvium consisting of clay, silt, sand and gravel ranging in thickness up to about 150 feet. Yields are usually in excess of 2,000 gallons per minute in indivual wells. Recharge capabilities range from poor to good with recharge hampered in much of the area by relatively thick, dense clay. Observation wells at Delta, Duck Creek and Naylor show quick response to precipitation, however. The principal use for water is for irrigation and this area could support a many-fold increase. The quality of this water is good, although it does contain iron which should be removed if the water is to be used by industries or municipalities. Some wells in the lowlands that are marginal to the bluff line penetrate the underlying carbonates.

Quality wise, this water is very similar to that in the alluvuim, and iron is a problem in rock wells.

The northern portion of Crowleys Ridge has exposures of carbonate rocks. Within this part of the ridge system water supplies must be developed by wells penetrating the carbonates. To the south, Crowleys Ridge is composed of soft, nonindurated sediments. Yields on the ridge commonly do not exceed 500 gallons per minute, regardless of the formation utilized.

East and southeast of Crowleys Ridge are alluvial materials with thicknesses ranging to more than 200 feet. Individual wells can readily obtain 2,000 gallons or more per minute. This alluvial water is used primarily for irrigation, although several municipalities, water districts and industries also use the water. Comparatively, there is less clay cover and hence better recharge conditions. The water quality is comparable to that on the west of Crowleys Ridge. Water levels on both sides of the ridge commonly range from less than one foot to some 15 feet below ground surface.

Cropping out along portions of Crowleys Ridge and underlying the alluvium to the east and southeast is the Wilcox Sandstone. These unconsolidated sediments, composed of clay and sand, are a prolific source of water. Thicknesses increase to the east and southeast and reach a total of more than 1,000 feet. Yields well in excess of 1,000 gallons per minute can be obtained over much of the area. Recharge is predominately from downward leakage from the alluvial materials, although there is some at its surface exposure along Crowleys Ridge. The chemical characteristics of the water are better than those of the alluvium. Cities which use the Wilcox as their water source are Sikeston and Charleston. An aquiclude (or barrier) separates this aquifer from the underlying McNairy aquifer.

The McNairy is referred to locally as the Ripley. It crops out along part of Crowleys Ridge; to the west of Crowleys Ridge in northwestern Dunklin County and southeastern Butler County, it directly underlies the alluvium. Qulin is the westernmost city utilizing the McNairy as its water source.

For those areas in which the aquifer is predominately a sand, yields range as high as 500 gallons per minute. To the east and the southeast there are increasing amounts of clay present, inhibiting the water yielding capabilities of the formation. In the past, where the McNairy was water-productive, the softness of the water induced most municipalities to use the McNairy as their source. Hardnesses commonly range from 15 to 25 parts per million. This is in contrast to the hardness of waters from the Wilcox and alluvium, which commonly range over 300 parts per million. In spite of this softness, chemical quality is not always good. Total dissolved solids exceed that which is permissible for public water supplies. The apparent base exchange which has caused softness has resulted in some ares having sodium levels in excess of 500 parts per million. Water in this formation is under sufficient hydrostatic head that throughout most of the area where it is utilized wells penetrating it flow under artesian pressure. Recharge is primarily from its exposure at the surface along Crowleys Ridge and from those areas where it directly underlies the alluvial materials. There is evidence of upward leakage from the underlying carbonates, and some of the higher mineral content originates from these underlying carbonates.

Eastward and southeastward from Crowleys Ridge the carbonates underlying the soft sediments are not used as a source of ground water. Generally the salinity of this water increases eastward. In eastern Mississippi County, oil tests have encountered water having total dissolved solids in excess of 40,000 parts per million.

The total ground-water resource of this area nearly equals that of the rest of the state. This very large ground-water resource, plus the water of the Mississippi River, precludes a water shortage in the foreseeable future.

Land Use

Proper land use in the Bootheel area requires detailed geologic investigation. Bedrock and soil conditions are highly variable. Twelve of the engineering geology bedrock-soil units designated by Hoffman in Stout and Hoffman (1973) are present in the county.

Unit one - Shallow Residual Soil Over Carbonate Bedrock (Ca-S)

This unit is in southern Ripley County. Bedrock consists of medium-bedded dolomite, and soil thicknesses range from 0 to 10 feet. The clay soil is relatively impermeable.

Sewage Lagoons. Satisfactory sewage lagoon sites are difficult to find because of the thin soil cover. In some cases, bentonite can be used to prevent leakage. Areas with thicker soils can be utilized satisfactorily.

Septic Tanks. Septic tanks should be used only in rural settings. The soils are too thin and impermeable to properly filter the effluent in most cases, and both surface and ground-water pollution are extremely likely.

Sewage Treatment Plants. Sewage treatment plants should only be used in conjunction with gaining streams such as the Current River.

Sanitary Landfills. Satisfactory landfill sites are difficult to locate because of the thin soil cover. Sites that can be utilized for landfills are generally small and could not satisfy the needs of a large town or city.

Impoundments. Small farm pond sites are easily located. Large impoundments can be built in some large creeks that have sustained flow. Soil for construction may not be adquate.

Construction. No problems are anticipated except in areas with steep slopes, where sliding may occur.

Unit Two - Intermediate-Thickness Residual Soil Over Carbonate Bedrock (Ca-I)

This unit is in portions of central and southern Ripley County and western Butler County. Bedrock consists of dolomite and cherty dolomite. Soil cover is generally a cherty-clay. Thicknesses usually vary from 20 to 40 ffet, but may be less locally. On-site investigation is necessary to determine the exact depth to bedrock at each proposed site.

Sewage Lagoons. Sites suitable for development as sewage lagoons can be located without great difficulty. If bedrock is encountered during excavation, remedial measures will be necessary. The soil cover in this unit is quite permeable, and clay padding or a bentonite and clay mixture will be necessary to keep leakage to a minimum.

Septic Tanks. Septic tanks should be restricted to rural areas where soil is more than 20 feet thick and should generally be limited to not more than one tank on each 3 acres. This is necessary to insure proper filtration of the sewage effluent. Septic tanks constructed where the soil cover is thin will cause pollution problems because of unfiltered effluent surfacing.

Sewage Treatment Plants. Because of the permeable nature of both bedrock and soil, most of the streams in this unit are losing. Treatment plant effluent should not be discharged into these streams because of the danger of polluting ground-water resources.

Sanitary Landfills. Sites suitable for development as sanitary landfills can be located with some difficulty. Remedial measures are necessary to prevent leachates from leaking into bedrock. If bedrock is encountered during construction, additional bedrock will have to be excavated from the site and replaced with a packed-clay pad.

Impoundments. Because of the permeable bedrock and soil, remedial measures are necessary to insure the success of small impoundments built in this unit. Larger impoundments may be impossible to seal effectively and may also fail because of catastrophic collapse.

Construction. Problems include possible catastrophic collapse.

Unit Three - Thick Residual Soil Over Carbonate Bedrock (Ca-T)

This unit is in portions of central and western Ripley County. Bedrock consists of dolomite and cherty dolomite. Soil cover is thick (40-100 feet) and is generally a stony-clay type.

Sewage Lagoons. Suitable sewage lagoon sites are difficult to locate. The soil and bedrock have high permeability, and leakage of effluent from the lagoon into the ground water system is likely. Remedial measures such as using bentonite and impermeable clays can be used to prevent this leakage in most cases.

Septic Tanks. The use of septic tanks should be restricted. Sparsely populated areas are best suited for this type of sewage treatment.

Sewage Treatment Plants. Most areas are unsuitable for this type of development. The high permeability of the soil and bedrock formations has resulted in a number of losing streams.

Treated effluent could easily enter the groundwater system and cause pollution problems.

Sanitary Landfills. Sites suitable for development as sanitary landfills can be located without great difficulty. Test pits should be dug at proposed sites to determine depth to bedrock. If the clay soil is too permeable, it may be possible to correct this problem by using bentonite mixed with clay to seal the floor and walls of the landfill site.

Impoundments. The same problems encountered in locating a suitable lagoon site are faced in selecting a site for an impoundment. The success of a small pond or lake will depend largely on the premeability of the soil at each proposed site.

Construction. Construction problems include local karst conditions, losing streams, variable strength of soils, and possible catastrophic collapse of bedrock.

Unit Four - Karst (Ca-K)

This unit is in portions of northwestern Ripley County. Bedrock consists of very permeable dolomite. Karst features such as caves and sinkholes are well developed throughout the area and present a considerable challenge to successful land development. Soil depths vary from 0 to over 100 feet thick, and generally the composition is a very cherty clay.

Sewage Lagoons. Sewage lagoons should not be used in this area. The high permeability of both soil and rock will prevent the lagoon from retaining effluent. Contamination can also occur from catastrophic collapse of bedrock supporting the lagoon structure.

Septic Tanks. Many problems are encountered in olcating suitable sites for septic tank development. Only those areas where thick, clay-rich soils are present should be considered. Septic tank use, in most cases, should be restricted to rural or farm settings where 3 acres or more are available as a filtration field for each tank.

Sewage Treatment Plants. Treatment plants should not be used except where effluent can be discharged without polluting the ground water. Because of the highly permeable nature of the soil and bedrock, discharge should be limited to streams with continuous flow.

Sanitary Landfills. Sites suitable for sanitary landfills are difficult to locate. Gullies and small, tight valleys with deeper, clay-rich soils are usually best. Remedial measures such as using a bentonite additive or clay padding for the lagoon floor are necessary to keep leachates from leaking into the soil and bedrock. Sinkholes should not be used for sanitary landfills because of the direct connection they have with the groundwater system.

Impoundments. Suitable sites are difficult to locate. Small farm ponds may be constructed, but remedial measures are probably necessary. Bentonite and/or impermeable clays usually can be used successfully to control leakage. There is some danger of catastrophic collapse with larger impoundments because of the increased load placed on the bedrock. Careful investigation is necessary to determine the strength of bedrock at all proposed sites.

Construction. Problems encountered include catastrophic collapse, variable soil depth to bedrock, and remnant bedrodk blocks (enclosed within soil).

Unit Five - Intermediate-Thickness Residual Soil Over Sandstone Bedrock (SS-I)

This unit is in northwestern Ripley County. Bedrock consists of massive sandstone and dolomitic sandstone. Overlying bedrock are soils which usually have a thickness of 20 to 40 feet, but the thickness may vary locally. The soil is primarily a silty or sandy clay.

Sewage Lagoons. Suitable sites are difficult to locate. Remedial measures are usually necessary to keep effluent from leaking into soil and bedrock. Packed clays or bentonite usually can be used successfully to prevent leakage.

Septic Tanks. Septic tanks can be successfully used where soil cover is from 30 to 40 feet deep. Septic tank density should not exceed one tank per 3 acres.

Sewage Treatment Plants. As with unit four, suitable sites are difficult to locate. Effluent lost to bedrock will usually cause some ground water pollution problems. Discharge points must be chosen carefully to prevent such pollution.

Sanitary Landfills. Sites suitable for development are difficult to locate because of the high permeability of bedrock and soil. In most cases, remedial measures are necessary to insure that leachates do not leak out of the landfill.

Impoundments. The same problems encountered when selecting a site for a successful sewage lagoon are faced here.

Construction. Problems encountered include catastrophic sinkhole collapse and moderate to severe hillslope erosion.

Unit Six - Thick Residual Soil Over Sandstone Bedrock (SS-T)

This unit is in portions of northern Butler County and northern Ripley County. Bedrock consists of Sandstone and dolomitic sandstone. A thick, silty clay or sandy clay overlies the bedrock in thicknesses that vary from 40 to 100 feet.

Sewage Lagoons. Selection of sites suitable for sewage lagoons depends largely on the permeability of soil cover. Some areas have a silty-clay soil that is sufficiently impermeable, but other areas have a very permeable, sandy-clay soil that is not suitable for development. Careful geologic investigation is necessary at each proposed site to determine soil permeability.

Septic Tanks. In most cases, septic tanks can be used. Because soil permeability is often high, it is recommended that septic tanks be limited to rural settings only.

Sewage Treatment Plants. Suitable sites can be located for effluent-discharge points but, because of the very permeable sandstone bedrock, it is recommended that discharge be limited to streams with perennial flow.

Sanitary Landfills. Suitable sites are difficult to locate because of the variable soil permeability. In many cases remedial measures such as using bentonite are necessary to prevent leakage of leachates. Exploration pits and borings, coupled with soil testing, may be necessary.

Impoundments. Problems are the same as those encountered in locating lagoon sites.

Construction. Problems include possible catastrophic sinkhole collapse, moderate to severe hillslope stability, and variable soil permeability.

Unit Seven - Poorly Consolidated Clays, Shales, Sands and Gravels (C-S)

This unit is in those portions of Dunklin, Scott and Stoddard Counties commonly called Crowleys Ridge. The bedrock formations consist of poorly indurated clay, shale, sandstone and gravel. Thickness of these deposits range from 250 to 350 feet.

Sewage Lagoons. Sites suitable for development can be located with some difficulty. The better areas have clay or shale bedrock. Sand and gravel areas should be avoided because these sand and gravel outcrops serve as recharge points for the area's ground water supply, and pollutants could easily enter the system.

Septic Tanks. The use of septic tanks is not recommended. The clay and shale layers, because of their high impermeability, do not adequately filter effluent. Effluent discharged in clay or shale areas surfaces and causes pollution problems. In those areas where sand or gravel are present, sewage effluent percolates too fast to be filtered properly, and groundwater pollution is likely.

Sewage Treatment Plants. Discharge from sewage treatment plants can be made into gaining streams.

Sanitary Landfills. Sites suitable for sanitary landfills are difficult to locate. Problems of permeability and ground-water pollution are similar to those encountered when dealing with sewage lagoons. Clay or shale bedrock areas are best.

Impoundments. No major problems are anticipated. Clay and shale areas are best suited for development.

Construction. Problems encountered include poor stability and bearing capacity.

Unit Eight - Very Thick Residual Soil (Re)

This unit is in northwestern Butler County and northeastern Ripley County. Bedrock is covered by very thick residual soil which consists primarily of stony, red clay that often contains "floating" bedrock blocks. Soil is usually more than 100 feet thick.

Sewage Lagoons. Sites suitable for sewage lagoons are difficult to find. Because of the moderate to high permeability of the soil, it is necessary to pad lagoon sites with compacted clays. If gravel beds are encountered during excavation, it is advisable to over excavate and repack with impermeable clay. When a lagoon is located in a creek valley, the floor of the lagoon should be kept above the groundwater level.

Septic Tanks. The success of any septic tank in this unit will depend largely on the amount of clay in the soil. Because of the varying soil permeability, septic tank use should be restricted to rural settings.

Sewage Treatment Plants. There are many losing streams in this unit because of the permeable nature of the soil. It is recommended that sewage treatment plant effluent not be discharged because of the danger of ground-water pollution.

Sanitary Landfills. Because of the permeable nature of the soil, a geologic investigation should be made before a decision is made on the suitability of any proposed site. In some cases it may be necessary to pad the landfill site with impermeable clays to prevent leakage of leachates.

Impoundments. Problems with impoundments are the same as those encountered when building a sewage lagoon.

Construction. Problems with construction include leakage from lagoons and landfills, and false bedrock surfaces caused by "floating" bedrock blocks.

Unit Nine - Alluvial Soil (Al)

This unit is not shown on the Hoffman map because of the unit's small size. It occupies the alluvial valleys of the area'a major streams--the Current, Black and St. Francis Rivers and their tributaries.

These valleys are deep and narrow and soil thicknesses vary from 0 to 40 feet. The soil is an admixture of gravel, sand, silt and clay.

Sewage Lagoons. The construction of a lagoon in this unit may lead to flooding of upstream developments, as well as downstream water pollution. Therefore, great care should be taken in selecting a lagoon site.

Septic Tanks. Septic tanks can be used with caution. Groundwater supplies are easily contaminated by improperly filtered septic tank effluent. Septic tanks can be used in rural areas where a 3 acre field (or larger) is available for filtration for each tank.

Sewage Treatment Plants. Treatment plants can be utilized here if discharge is limited to gaining streams.

Sanitary Landfills. Sites can be located away from the streams along the valley perimeter.

Impoundments. Lakes can be constructed with some difficulty. Each dam site should be overexcavated at the base and sides to insure that there will be no leakage around the dam. If permeable bedrock is encountered, the project may not be feasible because of increased costs.

Construction. Problems most often encountered include flooding, seepage, and varying soil strength.

Unit Ten - Thick Silty Alluvial Soil (Al-Tm)

This unit occupies portions of Butler, new Madrid, Ripley, Scott and Stoddard Counties. The alluvial soil is, for the most part, very silty and permeability is high. Thickness varies, but is generally greater than 40 feet.

Sewage Lagoons. Sites suitable for development as sewage lagoons are difficult to locate. Because of the high ground water table and problems with flooding, lagoons should be built on the surface and protected by levees. In some cases, it may be necessary to pad lagoon floors or seal them with bentonite to prevent downward leakage of pollutants.

Septic Tanks. The use of septic tanks is not recommended, even under rural conditions, because chances of polluting ground-water resources are great.

Sewage Treatment Plants. Many of the streams in this unit have sustained flow, and treated effluent can be safely discharge into them.

Sanitary Landfills. There are few sites suitable for development as sanitary landfills since the area's ground-water supply may be polluted by leaking leachates. Careful on-site geologic investigation is recommended before any site is considered for development.

Impoundments. Although small lakes and ponds can be constructed, these impoundments may be destroyed by flooding waters.

Construction. Problems include low wet-strength of the soil, high ground-water table, and flooding.

Unit Eleven - Thick Clayey Alluvial Soil (Al-Tc)

This unit is in portions of Dunklin, Mississippi, New Madrid, Pemiscot, Scott and Stoddard Counties. The alluvial soil is composed of clayey sand that becomes coarser with depth. Thickness of the soil is greater than 40 feet.

Sewage Lagoons. Very few problems are encountered since the clay-rich soil prevents leakage of polluted waters into the ground-water system. If gravels are exposed during excavation, the use of sealant is necessary.

Septic Tanks. The soil is not conducive to proper filtration of effluent, so septic tanks should not be used.

Sewage Treatment Plants. Effluent could be safely discharged into gaining streams.

Sanitary Landfills. Few problems are anticipated. The clay-rich soil is suitable for preventing leakage of leachates and for covering a fill site.

Impoundments. Few problems are encountered. Shallow ponds and lakes can be successfully built.

Construction. The most common problems encountered include low wet-soil strength and flooding.

Unit Twelve - Thick Sandy Alluvial Soil (Tl-Ts)

This unit is in portions of Dunklin, Mississippi, New Madrid, Pemiscot, Scott and Stoddard Counties. The alluvial soil is mainly composed of sand, but becomes coarser with depth. Thickness is greater than 40 feet.

Sewage Lagoons. Sites suitable for lagoons are difficult to locate. Impermeable clays, needed to seal lagoons, may not always be readily available nearby and may have to be imported. Without proper sealing, effluent can seep into the groundwater syste.

Septic Tanks. Septic tanks should not be used except in isolated cases. Groundwater pollution is almost a certainty.

Sewage Treatment Plants. Effluent can be discharged into gaining streams.

Sanitary Landfills. Sites are not generally suitable for development. The high permeability of the soil allows leachates to enter the groundwater supply.

Impoundments. Sites are difficult to locate because of high soil permeability.

Construction. Flooding is the only significant problem anticipated.

* * * For additional geologic information concerning this area see these selected references: 2, 3, 6, 7, 8, 13, 14, 15, 16, 17, 18, 20, 21.

BUTLER COUNTY, OZARK FOOTHILLS REGION

Summary

Butler County has a diverse topography which changes from a dissected plateau with relief as great as 270 feet in the northwest to a broad, flat plain with relief of only 20 feet at most in the southeast.

Bedrock formations consist of dolomite and sandstone. Surficial materials in the northwestern part of the county are mainly residual soils, while in the southeastern portion of the county the surficial deposits are primarily alluvial soils.

There is some danger of earthquake activity in Butler County.

Present mineral production is limited to clay for use in brick and tile manufacture. Known reserves are not large. Alluvial sand and gravel are present in large quantities in the lowlands. Resources of limestone are virtually non-existent, and high-specification construction aggregates are in short supply.

Water resources are plentiful. Both surface water and groundwater are utilized. The Black River supplies the water needs of Poplar Bluff and can supply additional quantities as the city grows. Other municipalities and industries obtain their water from groundwater sources. Domestic and farm needs are also met by utilizing groundwater.

Proper land use in Butler County will require careful on-site geologic investigation. Several engineering-geologic units are present, and the problems associated with waste disposal and construction vary with each unit. In general, waste disposal can be accomplished with minimum difficulty.

Problems encountered with geologically oriented development in Butler County will be also faced in the surrounding five counties.

This report is not intended to supply all the answers needed for development, but is intended to serve as a regional appraisal of the county's geologic features, resources, and problems. Careful on-site geologic investigation is recommended before any site is developed.

Landforms and Relief

The topography of Butler County is varied. The northern and western portions of the county, which lie within the Ozarks, are dominated by a highly dissected plateau. This plateau is characterized by long, ridge-like hills and narrow valleys. Relief is commonly 110 to 270 feet. In southern and eastern Butler County a low, flat plain is present. This area was once a part of the Mississippi River floodplain and has relief of only 5 to 15 feet. Floodplains of the county's major streams, the Black and St. Francis Rivers, are narrow (1/6-mile wide) in the northern part of the county, but become wider (1/3-mile wide) in the south.

Rock and Soil Formations

In the northern and western portions of the county, bedrock units consist primarily of thick, cherty dolomite and sandstone. Surficial materials are dominated by red, sandy, gravelly clay. This soil is generally thickest on hill tops and valleys. Thickness varies from 20 to 60 feet. In the lowlands, the alluvial soils are dominated by clays and sands. Total thickness of unconsolidated materials may be as much as 325 feet.

Earthquake Potential

Bedrock units within Butler County are flat-lying or gently dipping. The Pascola arch is the major structural feature. The arch extends from the center of Butler County southeast to Tennessee. The crest of the arch has long since been eroded and the arch is now only a subsurface feature. McCracken (1971, p. 49) believes the arch to be very slowly subsiding. Butler County lies near the recently active New Madrid fault zone and thus, is within an area of potential earthquake activity.

Scenic Natural Resources

Several caves and springs are found in Butler County. Keener pring has a daily discharge of about 13 million gallons

Mineral Resources

The mineral resources of Butler County are varied, but production is small.

<u>Sand and Gravel</u>. Significant reserves of sand and gravel are present along the Black River and its tributaries. Sand and gravel are commonly used as aggregate in ready-mix concrete and construction. Upland deposits are low-grade, and resources are small. Lowland deposits are large.

Clay and Shale. Clay mined from small deposits is used locally in the manufacture of brick and tile. Known reserves are not large, and the industry is not expected to grow.

Stone. Resources of limestone and dolomite are small. There is some potential in the northwestern part of the county for low-specification materials.

Iron. In the past, brown iron ore (limonite) was mined. Production declined because of small deposit size and variable ore quality. These mines are no longer in operation and future activity is not expected.

Water Resources

Poplar Bluff utilizes surface water from the Black River. Water needs are met in the hill country by wells penetrating carbonate rocks, and in the lowlands by wells penetrating the alluvium.

Surface Water. The Black River appears capable of meeting the future water needs of Poplar Bluff. However, if additional water supplies are needed, large volumes are obtainable from the alluvial materials in the lowlands to the east of Poplar Bluff.

Groundwater. Within the hill country, aside from red mud problems, no special problems are to be noted in obtaining water sufficient to supply homes and small industries. Home wells, commonly deeper than 300 feet, often have yields in excess of 25 gallons per minute. Probably, wells having depths of 1,000 to 1,200 feet could be drilled which would have yeild capabilities approaching 500 gallons per minute. This water has a chemical quality within the public health standards for public water supplies.

The thickness of the alluvium in the lowlands ranges to more than 100 feet. Wells having yield capabilities in excess of 2,000 gallons per minute can be constructed. A rather tight clay overlies the sands and gravels in some areas and inhibits recharge. Nevertheless, recharge is ample to support a many-fold increase in groundwater withdrawals. Present usage is primarily for irrigation. This water is of good chemical quality, but has an amount of iron which dictates its removal if it is to be used for municipalities or industry.

In southeastern Butler County, the McNairy Sand is present and directly underlies the alluvial materials. The town of Qulin uses this water-bearing formation as its source.

This water is of good chemical quality, very soft, and low in iron. Where present in Butler County as a water-productive sand, it yields water having such good quality that no treatment is required.

The underlying carbonate aquifers have very limited usage. With an abundance of water in the alluvium of comparable quality, it is not anticipated that the carbonate aquifers will be utilized in the future.

The water resources of Butler County are ample to meet all anticipated future growth.

Land Use

Proper land use in Butler County requires detailed geologic investigation. Bedrock and soil conditions are quite variable. Four of the engineering-geology bedrock-soil units designated by Hoffman *in* Stout and Hoffman (1973) are present in the county.

Unit One - Intermediate-Thickness Residual Soil Over Carbonate Bedrock (Ca-I)

This unit is in portions of west-central Butler County. Bedrock consists of dolomite and cherty dolomite, and soil cover is generally a cherty-clay type. Thicknesses usually vary from 20 to 40 feet, but may be less locally. On-site investigation is necessary to determine the exact depth to bedrock at each proposed site.

Sewage Lagoons. Sites suitable for development as sewage lagoons can be located without great difficulty. If bedrock is encountered during excavation, remedial measures will be necessary. The soil cover in this unit is quite permeable, and clay padding or a bentonite-and-clay mixture will be necessary to keep leakage to a minimum.

Septic Tanks. Septic tanks should be restricted to rural areas where soil is more than 20 feet thick and septic tank density is low (generally one tank per three acres). This will be necessary to insure proper filtration of the sewage effluent. Septic tanks constructed where the soil cover is thin will cause pollution problems because of unfiltered effluent surfacing or entering the groundwater.

Sewage Treatment Plants. Because of the permeable nature of both bedrock and soil, most of the streams in this unit are losing. Treatment-plant effluent should not be discharged into these streams because of the danger of polluting groundwater resources.

Sanitary Landfills. Sites suitable for development as sanitary landfills can be located without too much difficulty. Remedial measures are necessary to prevent leachates from leaking into bedrock. If bedrock is encountered during construction, additional bedrock will have to be excavated from the site and replaced with a packed-clay pad.

Impoundments. Because of the permeable bedrock and soil, remedial measures are necessary to insure the success of small impoundments built in this unit. Larger impoundments may be impossible to seal effectively and may also fail because of catastrophic collapse.

Construction. Problems include possible catastrophic collapse.

Unit Two - Thick Residual Soil Over Sandstone Bedrock (SS-T)

This unit is in portions of northern Butler County. Bedrock consists of sandstone and dolomitic sandstone. A thick, silty clay or sandy clay overlies the bedrock in thicknesses that vary from 40 to 100 feet.

Sewage Lagoons. The ease with which sites suitable for sewage lagoonds can be located will depend largely on the permeability of the soil cover. Some areas have a silty-clay soil that is sufficiently impermeable, but other areas have a very permeable, sandy-clay soil that would not be suitable for development. Careful geologic investigation is necessary at each proposed site to determine soil permeability.

Septic Tanks. In most cases septic tanks can be used within this unit. Because soil permeability is often high and underlying bedrock is a groundwater source, it is recommended that the use of septic tanks be limited to rural settings.

Sewage Treatment Plants. Suitable sites can be located for effluent-discharge points, but because of the very permeable sandstone bedrock, it is recommended that discharge be limited to streams with perennial flow.

Sanitary Landfills. Suitable sites are difficult to locate because of the variable soil permeability. In many cases, remedial measures such as using bentonite will be necessary to prevent leakage of leachates. Exploration pits and borings, coupled with soil testing, may be necessary.

Impoundments. Problems are the same as those encountered in locating lagoon sites.

Construction. Problems include possible catastrophic sinkhole collapse, moderate to severe hillslope instability, and variable soil permeability.

Unit Three - Very Thick Residual Soil (Re)

This unit is in the northwestern corner of Butler County. Bedrock is covered by very thick residual soil which consists primarily of stony, red clay that often contains "floating" bedrock blocks. Soil is usually more than 100 feet thick.

Sewage Lagoons. Sites suitable for sewage lagoons are difficult to find. Because of the moderate to high permeability of the soil, it is necessary to pad lagoon sites with compacted clays. If gravel beds are encountered during excavation, it is necessary to overexcavate and repack with impermeable clay. Where a lagoon is located in a creek valley it is recommended that the floor of the lagoon be kept above the groundwater level.

Septic Tanks. The success of any septic tank in this unit will depend largely on the amount of clay in the soil. Because of the varying soil permeability, it is recommended that septic-tank use be restricted to rural settings.

Sewage Treatment Plants. There are many losing streams in this unit because of the permeable nature of the soil. It is recommended that sewage-treatment-plant effluent not be discharged within this unit because of potential pollution of the groundwater.

Sanitary Landfills. Because of the permeable nature of the soil, a geologic investigation should be made before a decision is made on the suitability of any proposed site. In some cases it may be necessary to pad the landfill site with impermeable clays to prevent leakage of leachates.

Impoundments. Problems include those encountered when building a sewage lagoon.

Construction. Problems include leakage from lagoons and landfills, and false bedrock surfaces caused by "floating" bedrock blocks.

Unit Four - Thick Silty Alluvial Soil (Al-Tm)

This unit occupies the eastern and southern portions of Butler County. The alluvial soil is clayey to very silty. Permeability of the soil is low moderate. Thickness varies but is generally greater than 40 feet.

Sewage Lagoons. Sites suitable for development as sewage lagoons can be located with moderate difficulty. Because of the high groundwater table and problems with flooding, the lagoon should be built on the surface of the unit and protected by levees. In some cases, it may be necessary to pad the lagoon floor or seal it with bentonite to prevent downward leakage of pollutants.

Septic Tanks. The use of septic tanks is not recommended except in rural conditions. The chances of polluting the area's groundwater resources are great.

Sewage Treatment Plants. Many of the streams in this unit have sustained flow, and treated effluent could be safely discharged into them.

Sanitary Landfills. There are few sites suitable for development as sanitary landfills. Possible pollution of the area's groundwater supply by leaking leachates is a problem. Careful, on-site geologic investigation is recommended before any site is considered for development.

Impoundments. Small lakes and ponds can be constructed. However, these impoundments may be destroyed by flooding waters.

Construction. Problems include low wet strength of the soil, high groundwater table, and flooding.

* * * For additional geologic information concerning Butler County see these selected references: 2, 3, 6, 7, 8, 13, 14, 15, 16, 17, 18, 20, 21.