ORIGIN OF SINKHOLES AND RELATED FEATURES

Certain areas underlain by limestone and dolomite in Knox County contain many circular to elongate surface depressions (sinkholes), caves, springs, and disappearing streams generally arranged in a systematic fashion (fig. 1). These features result from the solution of the limestone and dolomite by surface and ground water. The type of landscape produced is so common worldwide in areas underlain by these rocks that a special term, karst, is used to describe it. Development of a karst landscape is dependent on the fact that limestone and dolomite are composed primarily (commonly 85 percent or more) of calcite (calcium carbonate) and dolomite (calcium magnesium carbonate), respectively, which are slowly dissolved in water charged with weak acid. Ground water charged with naturally produced weak organic acid causes the solution and removal of these minerals, developing pits, underground channelways, and caverns into which the land surface slowly settles, and into which surface water flows. This process produces an undulating surface with sinkholes and disappearing or nonexistent surface drainage. Disappearing streams are shown as noncontinuous stream lines on the map. Dolomite is much more abundant than limestone in Knox County (Harris, 1972a) and is slightly less soluble than limestone. However, whether the rock is limestone or dolomite makes little difference to the problems of karst terrain in Knox County.

Solution of these rocks tends to be concentrated along natural partings between individual rock layers (beds) and along abundant breaks (joints) that cut through the layers (fig. 2). The most strongly developed joint system in Knox County (Harris, 1972b) subdivides the individual limestone or dolomite layers into bricklike units. Movement of ground water and solution of the rock tend to be concentrated either parallel to the joint system or at the intersection of a joint with a bedding surface. Thus subsurface drainage patterns and solution systems generally closely approximate the original bricklike pattern of joints in the area (figs. 2*C* and 3). This strong influence of joint systems on the solution pattern in limestone or dolomite is clearly shown by the alinement of sinkholes (fig. 1) and by the pattern and shape of caves in Tennessee as shown by Barr (1961) and Matthews (1971).

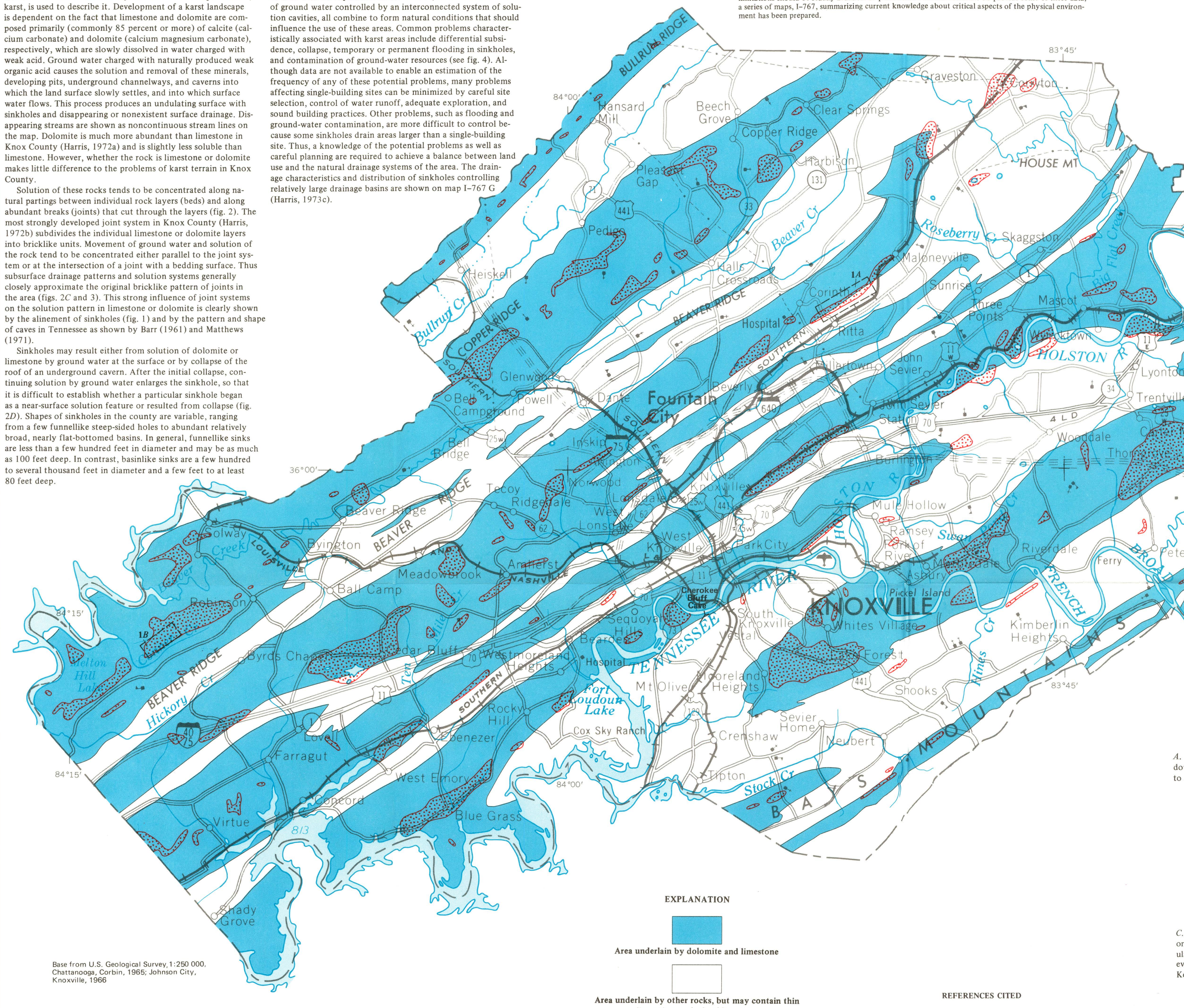
Sinkholes may result either from solution of dolomite or limestone by ground water at the surface or by collapse of the roof of an underground cavern. After the initial collapse, continuing solution by ground water enlarges the sinkhole, so that it is difficult to establish whether a particular sinkhole began as a near-surface solution feature or resulted from collapse (fig. 2*D*). Shapes of sinkholes in the county are variable, ranging from a few funnellike steep-sided holes to abundant relatively broad, nearly flat-bottomed basins. In general, funnellike sinks are less than a few hundred feet in diameter and may be as much as 100 feet deep. In contrast, basinlike sinks are a few hundred to several thousand feet in diameter and a few feet to at least 80 feet deep.

PROBLEMS COMMON TO KARST TERRAINS

Although all areas underlain by limestone and dolomite in Knox County contain at least some solution features, only those areas where solution has been intense enough to develop a sinkhole density similar to that shown in figure 1 are outlined on the map. In these selected karst areas, the abundance of sinkholes with no external drainage, the probable presence of subsurface cavities with no expression on the surface, and the movement of ground water controlled by an interconnected system of solution cavities, all combine to form natural conditions that should influence the use of these areas. Common problems characteristically associated with karst areas include differential subsidence, collapse, temporary or permanent flooding in sinkholes, and contamination of ground-water resources (see fig. 4). Although data are not available to enable an estimation of the frequency of any of these potential problems, many problems affecting single-building sites can be minimized by careful site selection, control of water runoff, adequate exploration, and sound building practices. Other problems, such as flooding and ground-water contamination, are more difficult to control because some sinkholes drain areas larger than a single-building site. Thus, a knowledge of the potential problems as well as careful planning are required to achieve a balance between land use and the natural drainage systems of the area. The drainage characteristics and distribution of sinkholes controlling relatively large drainage basins are shown on map I–767 G (Harris, 1973c).

LAND RESOURCE ANALYSIS MAPS OF KNOX COUNTY

Knox County has a 1972 population in excess of 270,000. The Metropolitan Planning Commission (1968) projects an increase in population to approximately 360,000 by 1990. As the population grows and favorable areas like west Knox County approach their limit of development, more and more marginal land will be utilized. In order to utilize the existing land resources safely and efficiently, and in order to maintain a suitable environmental quality, knowledge concerning the physical environment and its limitations should be readily available to planners and decision makers. To provide some of these data, a series of maps, I–767, summarizing current knowledge about critical aspects of the physical environment has been prepared.



Base from U.S. Geological Survey 1:250 000.
Chattanooga, Corbin, 1965; Johnson City,
Knoxville, 1966

SCALE 1:125 000

5 4 3 2 1 0 5 MILES

5 4 3 2 1 0 5 10 KILOMETERS

EXPLANATION

Area underlain by dolomite and limestone

Area underlain by other rocks, but may contain thin discontinuous beds of limestone

Area of abundant sinkholes and other solution features

Boundary between different rock units

Boundary of sinkhole areas

Areas shown in figures 1*A* and 1*B*

REFERENCES CITED

Barr, T.C., Jr., 1961, Caves of Tennessee: Tennessee Div. Geology Bull. 64, 567 p.

Harris, L.D., 1972a, Distribution of sedimentary rocks in Knox County, Tennessee: U.S. Geol. Survey Misc. Geol. Inv. Map I–767 C.

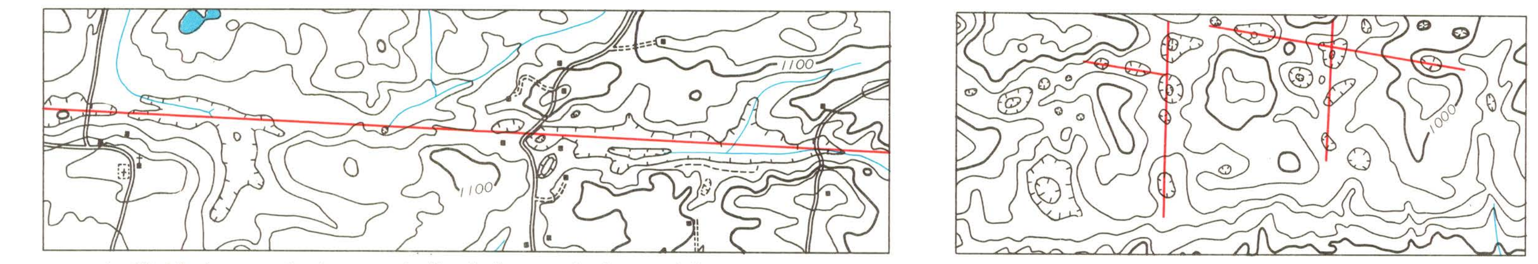
_____1972b, Structure map of Knox County, Tennessee: U.S. Geol. Survey Misc. Geol. Inv. Map I–767 D.

_____1973c, Selected drainage basins controlled by sinkholes in Knox County, Tennessee: U.S. Geol. Survey Misc. Geol. Inv. Map I–767 G.

Harris, L.D., and Kellberg, J.M., 1972, Engineering characteristics of overburden in Knox County, Tennessee: U.S. Geol. Survey Misc. Geol. Inv. Map I–767 K.

Matthews, L.E., 1971, Description of Tennessee caves: Tennessee Div. Geology Bull. 69, 150 p.

Metropolitan Planning Commission, 1968, General plan 1990, Knoxville, Knox County, Tennessee: Knoxville, Tenn., Metropolitan Planning Commission, 1 sheet, scale 1 inch = approx. 1 mile.



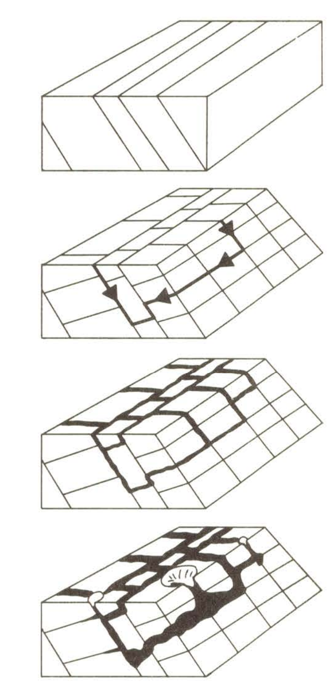
A. Sinkholes may be large and alined along a single trend (shown in red) with disappearing streams

OR

B. Individual sinkholes may be small and crudely alined along rectilinear trends (shown in red).

0 1000 2000 3000 4000 FEET

FIGURE 1. – Topographic maps showing typical karst areas in Knox County. Contour interval 20 feet. Sinkhole depressions shown by hachured contours. Location of areas *A* and *B* shown on the accompanying map as dashed rectangles.



A. Layers (beds) of limestone and dolomite, a few inches to several feet thick, are separated by natural partings. In Knox County most layers are inclined from a horizontal surface at varying degrees (Harris, 1972b).

B. Two sets of strongly developed breaks (joints) subdivide the layers into bricklike units. Surface water, seeking the easiest path of movement downward, follows openings provided by the joints and the natural partings between individual layers. Three possible directions of water movement are shown by the heavy lines with arrows.

C. Solution of limestone and dolomite by ground water enlarges the openings to form subsurface waterways.

D. Continuing solution both at the surface and in the subsurface results in the development of an integrated solution system consisting of numerous surface sinkholes of different sizes and shapes directly connected to subsurface caverns. In karst areas, surface streams are rare because sinkholes act both as collection areas for water and as conduits that direct surface water into an underground drainage system. Once in the system, water may flow underground great distances before being discharged at the ground surface in a spring.

FIGURE 2. – Diagrams showing development of a karst surface with an underground drainage system.

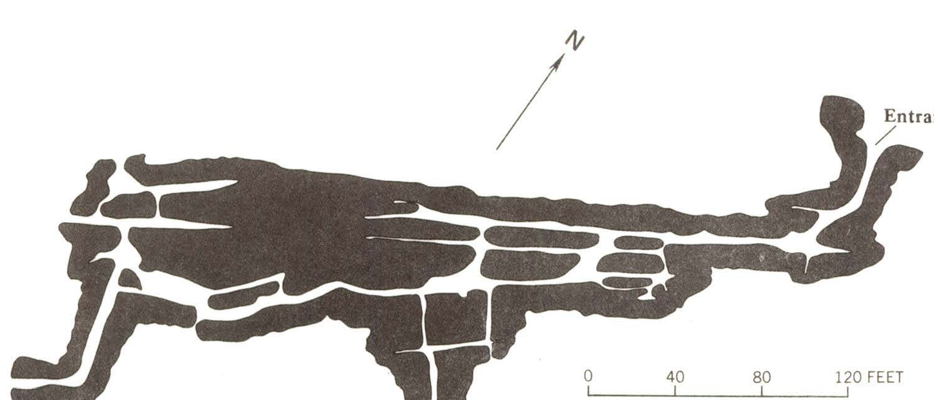
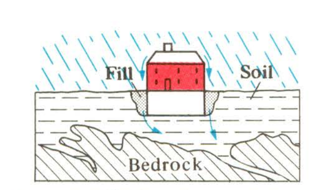
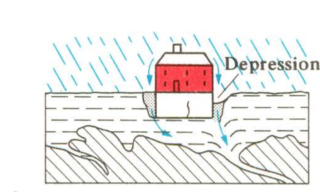


FIGURE 3. – Plan view of part of the Cherokee Bluff Cave, Knox County, showing that dissolved areas (white) in limestone (black) are not random, but follow a pre-existing joint pattern (modified from Barr, 1961).

SUBSIDENCE RESULTING FROM UNCONTROLLED SURFACE DRAINAGE

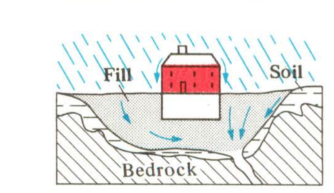


A. Uncontrolled surface water moves downward through porous fill and into a subsurface cavity.

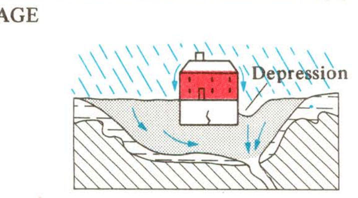


A′. If surface drainage is not controlled, continuing subsurface erosion may remove enough material to cause foundation damage as well as a depression on the surface.

SUBSIDENCE CAUSED BY UNCONTROLLED SURFACE AND SUBSURFACE DRAINAGE

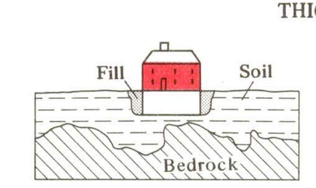


B. Sinkhole filled completely with soil material in an attempt to prepare a suitable building site without regard to the original drainage characteristics of the sinkhole.

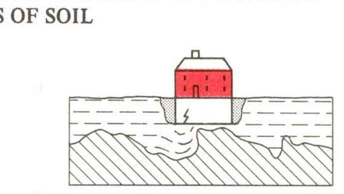


B′. Porous fill within the sinkhole may continue to transmit water to the original outlet in the base of the sink. Prolonged water movement may result in subsurface erosion and eventual foundation damage.

SUBSIDENCE RESULTING FROM UNEVEN SETTLING OF DIFFERENT THICKNESSES OF SOIL

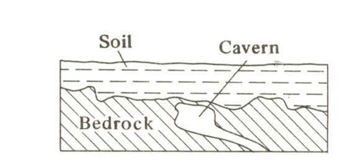


C. The bedrock surface of limestone or dolomite is characteristically irregular, so that the depth of soil is not everywhere the same (Harris and Kellberg, 1972).

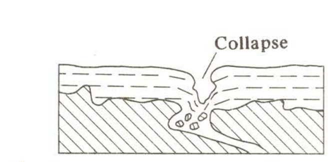


C′. Settling of soil caused by the load of a building is greatest where soil is thickest. If there are large differences in soil depth beneath a building, uneven settling may cause foundation damage.

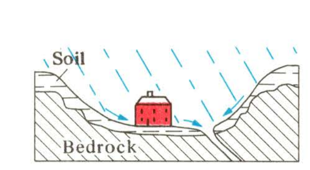
SUBSIDENCE RESULTING FROM COLLAPSE



D. Subsurface caverns with no surface expression may be present in areas underlain by limestone or dolomite.



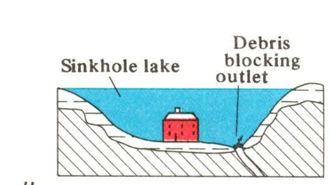
D′. Sudden appearance of a sinkhole due to the collapse of a cavern roof is not uncommon. If a building is near the collapse, extensive damage will result.



E. During periods of low rainfall, water draining into a sinkhole may be discharged quickly and completely through the outlet in the base of the sinkhole.

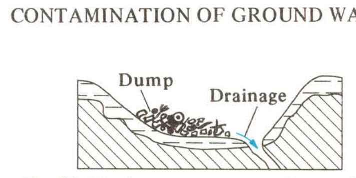
FLOODING OF SINKHOLES

E′. During periods of heavy rainfall, the outlet in the base of a sinkhole may not be large enough to discharge quickly a sudden surge of water, resulting in temporary flooding.



E″. If the outlet in the base of a sinkhole becomes plugged by debris or by underground collapse, drainage may be blocked, resulting in a sinkhole lake.

CONTAMINATION OF GROUND WATER



F. Sinkholes are commonly used as dumps without the user realizing that the outlet is directly connected to the subsurface ground-water system. Water draining from the dump may go directly into the ground-water system, resulting in contamination.

FIGURE 4. – Common problems of karst terrains.

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AREAS WITH ABUNDANT SINKHOLES IN KNOX COUNTY, TENNESSEE

By
Leonard D. Harris

1973

Blackline copies of this map are available at cost on transparent scale-stable material from the U.S. Geological Survey, Washington, D.C. 20242

For sale by U.S. Geological Survey, price 75 cents