Catastrophic Subsidence: An Environmental Hazard, Shelby County, Alabama

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ABSTRACT / Induced sinkholes (catastrophic subsidence) are those caused or accelerated by human activities. These sinkholes commonly result from a water level decline due to pumpage. Construction activities in a cone of depression greatly increase the likelihood of sinkhole occurrence. Almost all occur where cavities develop in unconsolidated deposits overlying solution openings in carbonate rocks. Triggering mechanisms resulting from water level declines are (1) loss of buoyant support of the water, (2) increased gradient and water velocity, (3) water-level fluctuations, and (4) induced recharge. Construction activities triggering sinkhole development include ditching, removing overburden, drilling, movement of heavy equipment, blasting, and the diversion and impoundment of drainage. Triggering mechanisms include piping, saturation, and loading.

Induced sinkholes resulting from human water development/management activities are most predictable in a youthful karst area impacted by groundwater withdrawals. Shape, depth, and timing of catastrophic subsidence can be predicted in general terms.

Remote sensing techniques are used in prediction of locations of catastrophic subsidence. This provides a basis for design and relocation of structures such as a gas pipeline, dam, or building. Utilization of techniques and a case history of the relocation of a pipeline are described.

Introduction

The sudden formation of sinkholes or “catastrophic subsidence” in recent years has focused attention on a little-understood geologic hazard. Few people realize that thousands have formed in the United States since 1950. Costly damage, some accompanied by injuries and loss of life, has resulted from sudden collapses beneath highways, railroads, bridges, buildings, dams, reservoirs, pipelines, vehicles, and drilling operations. Perhaps one of the most spectacular was the “Golly Hole” collapse on December 2, 1972, in Shelby County, Alabama; another was the surface collapse of part of a city block in Winter Park, Florida, in 1981.

Sinkholes can be separated into categories defined as “induced” and “natural.” Induced sinkholes are those caused or accelerated by human activities, whereas natural ones occur in nature. Recognition of induced sinkholes or catastrophic subsidence, the subject of this article, and their investigation has been confined mainly to this century. Almost all investigations dealing with triggering mechanisms or processes have been made since 1950.

The purpose of this article is to present a review of geologic and hydrologic mechanisms triggering the development of induced sinkholes resulting from water level declines, to identify predictive capabilities relating to sinkhole occurrence, and to describe techniques used in a case history to relocate a gas pipeline in a highly vulnerable karst setting.

General Hydrogeologic Setting

The karst terrain chosen to illustrate catastrophic sinkhole development is Dry Valley, Shelby County, Alabama (Fig. 1). It is a youthful basin that contains a perennial or near-perennial stream. Water is stored in underlying carbonate rocks and moves through interconnected openings along bedding planes, joints, fractures, and faults, some of which are enlarged by solutioning. Recharge from precipitation, in response to gravity, moves downward into this system of openings or toward the stream channel where it discharges and becomes streamflow. A schematic cross section illustrating the conditions described is shown in Figure 2.

Water in rocks underlying the basin occurs under water table and artesian conditions; however, this study is concerned with water table conditions. The configuration of the water table conforms to that of the topography but is also influenced by precipitation, geologic structure, and water withdrawal. Bedrock openings underlying lower parts of the basin are water-filled and those underlying upland areas north of County Highway 16 (Fig. 1) are air-filled.

A mantle of unconsolidated deposits resulting from the solution of the underlying rocks consists chiefly of residual clay (residuum). This clay commonly contains...
Geology of the Dry Valley Area

Dry valley is within the Cahaba Valley District of the Valley and Ridge physiographic province which is characterized by northeast-southwest trending valleys and ridges. The Cahaba Valley was formed by differential erosion of folded and faulted rock formations com-

chert debris and covers most of the bedrock surface. Alluvial or other unconsolidated deposits often overlie the clay adjacent to streams. The contact between residuum and underlying bedrock is highly irregular because of differential solution of the bedrock. Unconsolidated deposits commonly fill openings in bedrock to depths of 30 or more feet.

Figure 1. Location of study area.