Identifying the Primary Factors that Determine the Occurrence of Sinkholes in the Ozarks

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In May 2004, resource managers and scientists from the National Park Service, U.S. Fish and Wildlife Service, and U.S. Geological Survey (USGS) met in Fayetteville, Arkansas to identify Ozarks resource issues and to commit to a cooperative interdisciplinary research partnership. During that meeting, representatives from the three participating agencies identified a process that included identifying focus areas, identifying a flagship issue, and creating an inventory of karst resources. Since then, the USGS has committed five years of funding for an interdisciplinary project focused on identifying the major factors that determine the occurrence of sinkholes and how they affect physical, biological, and social processes.

Setting:

The Ozark Plateaus of southern Missouri and northern Arkansas are a temperate, mostly forested region that is one of the oldest continually exposed landscapes on earth. Plants and animals have had over 200 million years to adapt to the rugged landscape, or take refuge from continental climate change. Its geographic isolation, topographic relief, karst geology, and good water quality have resulted in remarkable biodiversity. The plateau is underlain by widespread, gently dipping limestone and dolomite formations that are known for their well developed karst features. Sinkholes, caves, springs, and gaining and losing streams, define the hydrology of much of the Ozarks. Streams in the region are particularly vulnerable to rapid and unpredictable changes in water quality. Sinkholes and other point recharge locations provide a direct pathway for point source contaminants—from leaks, impoundment failures, or spills—or non-point source contaminants from land use practices to enter the subsurface. This study is focused on two sites: The Ozark National Scenic Riverways, located along the Current River and Jacks Fork of the Current River, and The Buffalo National River in northern Arkansas. Both sites are managed by the National Park Service.

A typical Ozark landscape.

A typical Ozark stream.

Objective of the Project:

The objective of this project is to use surface form, surface features, and selected biological, hydrological, and geological characteristics of the landscape to develop a probabilistic model for identifying the major factors that determine the occurrence of sinkholes in the Ozarks. The locations of Ozark springs and caves are well documented. The locations of larger and better known springs and caves are typically symbolized and labeled on topographic maps. The locations of smaller or lesser known features can be found in digital and tabular inventories maintained by a variety of federal, state, and local agencies and organizations. The locations of sinkholes are not as well documented as attempts to map and document sinkholes have been only partially successful due to their size, lack of surface expression, or geographic isolation.

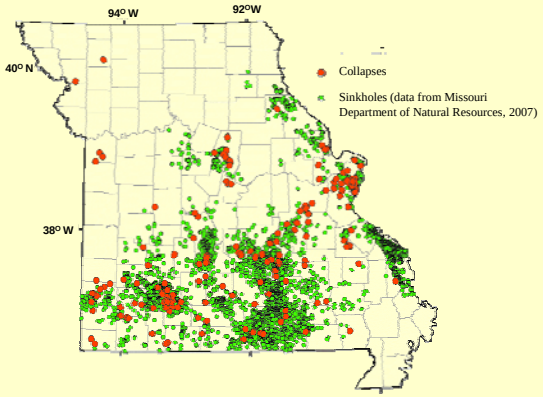
Accurately identifying the location of sinkholes is critical to ensuring a more complete understanding of the hydrology of karst landscapes, and to anticipating the consequences of contaminants being introduced into the system. More importantly, knowing the factors that contribute to sinkhole formation and the ability to predict where sinkholes are likely to exist or suddenly occur is important to understand fully the effects of various planned or preexisting land use activities on the quality of surface and subsurface water in the Ozarks, and to mitigate the threat associated with the catastrophic collapse of a sinkhole in an urban area.

Identifying and Mapping Sinkholes:

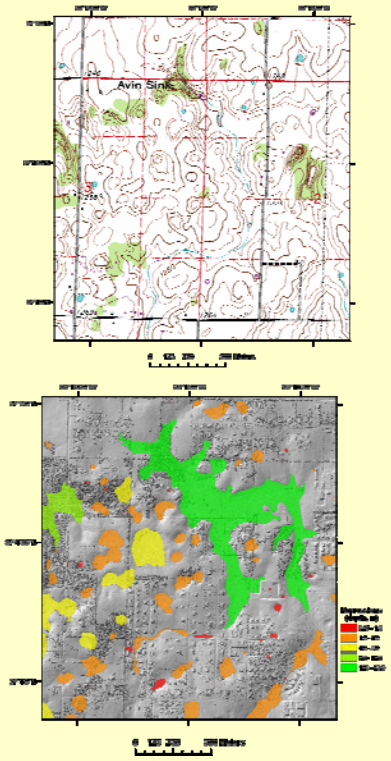
There have been a variety of methods used to identify and map sinkholes in the Ozarks that include extensive field-based reconnaissance, visual interpretation of aerial photographs, and the analysis of digital elevation data. Larger sinkholes are typically symbolized with depression contours on USGS large-scale topographic maps, and uniquely attributed in USGS digital line graphs making their visual identification or digital selection relatively easy. Consequently, maps can be generated based on the selection, either visually or analytically, of the depression contours. Unfortunately, sinkholes that do not meet minimum mapping standards, are not deep enough to have topographic expression, or are obscured by vegetation would not be identified and symbolized on topographic maps, interpolated on digital elevation models, or digitized and attributed on digital line graphs.

Recently, high resolution Light Detection and Ranging (LIDAR) data, and digital image processing and feature recognition techniques have been used to map sinkholes in southwestern Missouri. This approach shows promise, but the data are expensive, possibly unsuited to regional analyses, and the approach relies on the analysis of the shape of the ground surface, identifying depressions of various sizes that may or may not be sinkholes. Consequently, ancillary data that describe or define other biological and physical characteristics of karst landscapes must be included in the analysis to ensure the accurate delineation of sinkholes or areas where sinkholes are likely to exist.

These diagnostic biophysical characteristics can include various attributes of the hydrology (such as the pattern, orientation, and the ratio of first to higher ordered streams); the geology (such as the orientation of joints and fractures, depth to and type of bedrock, and the distribution and number of existing sinkholes); the biology (such as the location of particular plant assemblages, and the response of plant assemblages to site-specific differences in soil moisture); or geography (such as elevation, or regional patterns of surface roughness) that can be directly measured in the field, remotely sensed, or derived from existing data. In addition, the correlation of one or more of these characteristics may also be diagnostic of areas with sinkholes, or where sinkholes are likely to occur.



Distribution of collapses and sinkholes in Missouri.



A topographic map (top) and a shaded relief image (bottom) of sinkholes in an area northwest of Nixa, Missouri. The shaded relief image was generated from LIDAR data acquired in 2006. Sinkholes are symbolized by depression tics on the map and by colored polygons on the image that were analytically derived from the LIDAR data.

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