Hierarchical Systems Analysis in Karst Terrains:

Part A. Approaches and Applications to Environmental Characterization

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Abstract

As global populations increase, natural aggregate resources (sand, gravel, and stone) are needed to build and maintain the human system infrastructure. Producing aggregate in an environmentally safe manner commonly requires environmental assessments. To minimize environmental damage, potential environmental impacts should be identified, characterized, and evaluated. A hierarchical systems analysis (HSA) has been designed to characterize the environmental system components, identify potential impacts to those systems, and evaluate the extent of those impacts.

The landscape can be viewed as a mosaic of dynamic systems that operate through complex interrelated processes. By understanding how systems behave separately, one can predict how they will behave collectively. A prediction can be derived by using a step-wise hierarchical method (HSA) to qualitatively conceptualize and quantitatively characterize how aggregate extraction, for example, will impact the environmental system. HSA is iterative and begins with problem definition. Preliminary conceptualization and characterization is based on existing data, field characterization, and general principals, followed by analysis and a refinement of understanding. Subsequent data collection, data analysis, and further refinement are conducted as necessary.

HSA is used to analyze various systems, including climatic, land surface, surface water, geomorphic, subsurface, and the geohydrologic systems. The understanding of each system hierarchically depends on the understanding of the others, and culminates in the characterization of the environmental system. HSA uses a step-wise approach to break complicated issues down into smaller, easier to understand, components. This increased understanding may enable consensus building between permitting agencies and the mining industry personnel. HSA can also be used to identify and characterize aggregate resources or to develop and implement environmental management systems.

A case history of the Carlsbad Caverns National Park, USA , a world biosphere site, illustrates HSA for analyzing the environmental system and for risk analysis. Carlsbad Caverns National Park, a visitor accessible cave system located in the southeastern corner of New Mexico, USA, contains numerous caves in the underlying fractured limestone. To support and manage the increasing number of visitors, the U.S. National Park Service has created an extensive infrastructure with facilities both above ground and underground. The focus of this project was to determine the potential impacts of man-made structures and human activities at the land surface at Carlsbad Cavern, and to determine the cave areas most vulnerable to contamination from the land surface through hydrologic pathways.

The HSA approach, augmented by a series of physical measurements and chemical sampling to determine the amount and distribution of general and anthropogenic chemical characteristics of percolating water, was used to facilitate the environmental systems characterization and risk assessment. This study is analogous to an underground mining operation with associated surface and subsurface infrastructure in karst terrain.

Part B of this paper (Part B read me) describes how HSA can be used to characterize and analyze the potential environmental impacts of aggregate mining in karst terrains.