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Spatial Mapping of Karstic Cave Structures by Means of Airborne Electromagnetics: an Emerging Technology to Support Protection of Endangered Karst Systems

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Karst covers approximately 12% of the earth's land surface and karst aquifers are important water resources in many parts of the world. About 25% of the world population depend on karst aquifers for water supply. Due to the rapid flow in karst aquifers, these water resources are extremely vulnerable to environmental pollution. Therefore protection of karst areas is of major concern to ensure adequate water supply to the earth's population. In order to protect karstic groundwater systems and associated ecosystems, it is necessary to set up integrated simulation tools for sustainable management of these resources based on accurate coupled surface-/groundwater models. Although the mathematical formulation of such models is well established, results are mostly unsatisfactory. The reason for that is that location and geometry of dominant karst features, controlling the flow, are either not known at all or not known with the required accuracy. Therefore hydrological modelling of karst aquifers could significantly advance if new and innovative technologies are developed to provide the necessary input data. Within the presented study we have tested the potential of airborne geophysical techniques to provide innovative input information for improved groundwater modelling of karst aquifers. As a follow up of a first assessment of the subsurface situation in 2006 by means of ground geoelectrics, a pilot airborne geo-

physical survey was performed in spring 2007. For this study, the Austrian airborne system (Motschka, 2001) was used, comprising frequency domain electromagnetics, magnetics, gamma ray and infrared mapping. As a test area, the Sian Ka'an Biosphere Reserve (SKBR; Morales, 1992, 1993, 1995), located in Yucatan / Mexico, was chosen due to its uniquely favourable conditions for the application of the frequency domain airborne electromagnetic techniques (FDEM). Furthermore, negative effects of urban development and agriculture pose an acute threat to the karstic aquifers representing the lifeline of the reserve. SKBR is a coastal wetland of international importance. The primary management questions arising in SKBR are related either to the rapid tourism development in and around the reserve or to the impact of intensified agriculture and land-use changes in the surrounding areas. The underground hydrologic system in the study site is a key ecological link between the tropical forest, wetlands, coral reef and other marine ecosystems, as well as the human activities associated to those environments. The municipality of Tulum, located a couple of kilometers North of the SKBR, is currently in the process of designing an urban development plan (Plan de Desarrollo Urbano, PDU). The preliminary version of the PDU promotes the establishment of 60,000 hotel beds in Tulum. Tulum presently has about 12,000 inhabitants and the PDU foresees at least a tenfold increase in the local population. The urban area is expected to expand significantly reaching the border of the SKBR in the south. As a reaction to stakeholder concerns, the municipality has established technical committees to re-evaluate aspects regarding the sustainability and feasibility of the plan, including hydrological and hydrogeological issues. Therefore results of our research project will directly feed into the local decision-making process. Evaluation of the acquired data showed, that the subsurface cave system, partly investigated by cave diving surveys, could be mapped with high accuracy using the results from the FDEM. Additionally several previously unknown cave systems could be located. However, advanced processing algorithms have to be developed in future to derive quantitative information on depth and size of the caves, as conventional one dimensional multi-layer inversion procedures have not succeeded to derive these parameters.

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