Proceedings of the Union Internacionale de Speleologie (UIS)
/ International Union of Speleology
Athens, Greece, August 21-28, 2005

DECOUPLED AND DEPTH STRATIFIED CIRCULATION IN A COASTAL CARBONATE AQUIFER: YUCATAN PENINSULA, MEXICO

Beddows, P.A. [1*], P.L. Smart[2], S.L. Smith[3], F.F. Whitaker[4]

[1]School of Geography and Earth Sciences, McMaster University, Hamilton L8S 4K1 Canada *beddows@mcmaster.ca
[2]School of Geographical Sciences, University of Bristol, Bristol BS8 1SS UK
[3]Department of Earth Sciences, University of Toronto, Toronto M5S 3B1 Canada
[4]Department of Earth Sciences, University of Bristol, Bristol BS8 1RJ UK

The conventional model for saline groundwater circulation in coastal carbonate aquifers is that a shallow zone of saline outflow is entrained coastward by the discharge of the overlying fresh water lens, with a compensatory inflow of sea water at depth. However, this model is supported by only a limited number of field observations as *in situ* monitoring of groundwater circulation remains logistically challenging. Here we present an alternative model based on instrumental records (velocity, salinity, temperature) and dye tracing of groundwater circulation in extensive flooded cave systems on the Caribbean coast of the Yucatan Peninsula, Mexico. The conduits are the focus of this study as they account for >99% of the aquifer flux.

The saline flow to ~5 m below the fresh-saline mixing zone is modulated by the semi-diurnal tides, while lower frequency alternating cycles of net inflow and outflow correspond to the annual periods of high and low Caribbean sea levels. The shallow saline groundwater temperatures are comparable to that of the Caribbean seawater at the coast but decline by 1.8^{o}C at 9 km inland indicating that the saline inflow penetrates far into the aquifer. The semidiurnal tides impound the fresh water on top of the mixing zone during high tides, however all data indicate a persistent net discharge of fresh water regardless of mean sea level. The reversing shallow saline groundwater circulation is therefore decoupled from the coastward freshwater discharge. As a result, the mixing zone within the conduits is characterised by very steep density gradients and strongly sheared flows.

In contrast to the reversing shallow saline circulation, velocity measurements of deeper saline water in three conduits to depths of 45 m below the mixing zone indicate continuous inland flow irrespective of mean Caribbean sea-level. Whilst this is consistent with the conventional circulation model, it may also indicate a unidirectional cross-platform circulation channelling water from the Caribbean Sea into the Gulf of Mexico, the drive for which may be a head difference across the platform. A limited number of deeper profiles reveal a second but smaller density interface a few metres below the mixing zone suggesting shear and decoupling between the shallow and deep saline flow regimes. The pathways for the cross-platform saline flows may in part be via a deeper tier of karstification formed during previous low sea levels.

These results challenge the conventional circulation model specifically by providing direct observation of decoupling of fresh and saline groundwater flows across the mixing zone, although we recognise that further research is required to confirm the proposed deeper cross platform saline circulation. Our findings present new insight into speleogenetic processes in density stratified carbonate aquifers, as well as indicate the difficulty of predicting the fate of effluent pumped into the saline water.