Evaluating Freshwater Lens Vulnerability in a Multi-layered, Island Aquifer System in the Tropics

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Groundwater is the primary source of freshwater supply on remote small islands, where it exists as a freshwater lens. It is extremely vulnerable to over-extraction, pollution and seawater intrusion. Ensuring long-term sustainable management of the groundwater resource is of the utmost importance when there are growing water demands, sea-level rise and/or recharge decline. This study used a three-dimensional, variable-density numerical groundwater flow and solute transport model to investigate vulnerability of a freshwater lens in a multi-layered aquifer system on Milingimbi Island, a small tropical island in northern Australia. The model was used to explore the impacts and possibility of increased groundwater demand on the freshwater lens, its volume, geometry as well as the thickness of the transition zone. The risks of saltwater intrusion, both laterally from the ocean and by localised up-coning from the deeper, more saline aquifers beneath the freshwater lens, were also assessed. Model calibration used observed hydraulic heads and salinity observations from pumping and observation wells. Subsurface bulk conductivity values, which were calculated from inverted airborne electromagnetic (AEM) and near-surface geophysical data, were also used in the calibration process. The results showed that the hydraulic heads and observed salinity achieved the ‘best fit’ in the calibration process, whereas the addition of the geophysical data assisted in constraining the lens geometry in the steady state model and integrated the data poor areas based on traditional hydrogeological datasets. The models’ calibration sensitivity to the range of measured salinities could be enhanced by improving the conversion factor between the AEM-derived conductivity values and the observed salinity data. This would best be accomplished by targeted monitoring wells at discrete depths and locations across the lens and improvements in the sampling/restoration of existing ones. The numerical model provided a framework to evaluate the key underlying hydrogeological processes on the island, as well as an important decision-making tool to ensure a sustainable and reliable water supply for the island community.