Aquifer compaction–a threat to coastal aquifers

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ABSTRACT
Fine-grained sediments are susceptible to inelastic compaction in response to groundwater withdrawals in many coastal aquifers in the world. Inelastic compaction of fine-grained aquifer sediments results in land subsidence, which can increase the threat of saltwater intrusion and the frequency and intensity of flooding. The adverse effects of inelastic compaction and subsidence resulting from groundwater withdrawals have been observed in coastal aquifers in the Chicot and Evangeline aquifers in Houston Texas, USA; the Ganges-Brahmaputra Delta, Bangladesh; Jakarta basin aquifer, Indonesia; the lower Mekong Delta, Cambodia and Vietnam; and the Virginia Coastal Plain aquifer system, USA.

Changes in the effective stress resulting from changes in the hydraulic and geostatic stress in an aquifer cause compaction of fine-grained sediments. Inelastic compaction of fine-grained sediments is permanent and occurs when the effective stress exceeds the previous pre-consolidation stress value in an aquifer. A compaction (IBC) package has been developed for MODFLOW 6 that can simulate elastic and inelastic compaction of fine-grained interbeds resulting from changes in hydraulic and geostatic stresses in an aquifer. The IBC package can also simulate storage changes resulting from compaction in relatively thin interbeds of fine-grained sediments that equilibrate quickly with water-levels in coarse grained aquifer materials and thick interbeds of fine-grained sediments that drain slowly in response to water-levels changes in coarse grained aquifer materials.

The IBC package has been applied to a model developed for the Chicot and Evangeline aquifers in Houston Texas. Land subsidence and loss of 100 km^2 of wetlands around Galveston Bay has occurred in the Houston area since development of the area began in 1891. Fine-grained interbeds in the Chicot and Evangeline aquifers have an average thickness of 5 meters and total thicknesses that range from 150 to 760 meters and 30 to 210 meters, respectively. The fine-grained interbeds in the Chicot and Evangeline aquifers are relatively thin and were simulated as no-delay interbeds. Simulated model results indicate that maximum compaction in the Chicot and Evangeline aquifers is 3 meters and 2 meters, respectively, which contribute to a maximum of 3 meters of land subsidence in the Houston area. Simulated maximum land subsidence rates during periods with high groundwater withdrawal rates range from 47 to 130 mm/y, which exceed current global estimates of sea-level rise (~3 mm/y).

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