XVIII International Conference on Water Resources
CMWR 2010
J. Carrera (Ed)
CIMNE, Barcelona 2010

# STOCHASTIC ANALYSIS OF THE VENICE UPLIFT DUE TO SEAWATER INJECTION INTO DEEP AQUIFERS

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**Summary.** In recent years, several geo-mechanical modeling studies have indicated that seawater injection into deep formations underneath the city of Venice, Italy, may produce a land uplift sufficient to significantly mitigate the effects of the "acqua alta", that is, the exceptional tide peaks that periodically occur in the northern Adriatic Sea. However, of major concern is the differential vertical displacement at the ground surface, which must not exceed prescribed regulatory thresholds to guarantee structural preservation of the city historical buildings. In this work, we focus on the hydraulic conductivity, K, which - due to its inherent spatial heterogeneity - is often one of the most difficult hydrogeological parameters to characterize, and analyze the effects that spatially heterogeneous aquifer K distributions may have on the uniformity of the induced land uplift. This study relies on a series of stochastic geo-mechanical simulations performed using an uncoupled 3D finite-element model poro-elastic model and refers to a pilot project devised to address the feasibility and sustainability of an actual full-scale injection program. The pilot project considers the recharge of about 3,100 $m^3$/day seawater over three years from three injection wells installed into six aquifers comprised between depths of 600 and 850 meters. The K field is modeled geostatistically according to an unconditional, second-order, stationary random process characterized by an exponential covariance function. The stochastic geo-mechanical simulations are structured into a sensitivity analysis in order to investigate the impact of the variance, $\sigma^2$, and the horizontal correlation scale, $\lambda$, of the K field on the spatial distributions of the ground surface uplift and its horizontal gradient $\rho_z$. The results indicate that, irrespective of the $\sigma^2$ and $\lambda$ values, properly selected within the ranges 0.2-1.0 and 20-1000 m, respectively, typical of normally consolidated sedimentary basins, the predicted uplift is substantially regular with negligible differential displacements. Even under the most pessimistic scenario ($\sigma^2$=1.0 and $\lambda$ =1000 m) the maximum $\rho_z$ results from two to three times smaller than that experienced by the city over the 1960's due to ground water pumping ($10\times10^{-5}$), one order of magnitude less than the maximum limit allowed for masonry buildings ($50\times10^{-5}$), and about 20 times smaller than the maximum values that the city is currently experiencing due to surficial loads and to possible subsoil heterogeneities.