A New Method to Infer Advancement of Saline Front in Coastal Groundwater Systems by 3D: The Case of Bari (Southern Italy) Fractured Aquifer

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Abstract: A new method to study 3D saline front advancement in coastal fractured aquifers has been presented. Field groundwater salinity was measured in boreholes of the Bari (Southern Italy) coastal aquifer with depth below water table. Then, the Ghyben-Herzberg freshwater/saltwater (50%) sharp interface and saline front position were determined by model simulations of the freshwater flow in groundwater. Afterward, the best-fit procedure between groundwater salinity measurements, at assigned water depth of 1.0 m in boreholes, and distances of each borehole from the modelled freshwater/saltwater saline front was used to convert each position (x, y) in groundwater to the water salinity concentration at depth of 1.0 m. Moreover, a second best-fit procedure was applied to the salinity measurements in boreholes with depth z. These results provided a grid file (x, y, z, salinity) suitable for plotting the actual Bari aquifer salinity by 3D maps. Subsequently, in order to assess effects of pumping on the saltwater-freshwater transition zone in the coastal aquifer, the Navier-Stokes (N-S) equations were applied to study transient density-driven flow and salt mass transport into freshwater of a single fracture. The rate of seawater/freshwater interface advancement given by the N-S solution was used to define the progression of saline front in Bari groundwater, starting from the actual salinity 3D map. The impact of pumping of 335 L s⁻¹ during the transition period of 112.8 days was easily highlighted on 3D salinity maps of Bari aquifer.

Keywords: coastal aquifers; tracer tests; over-abstraction; modeling; salinity maps in 3D

1. Introduction

Groundwater over-abstractions typically can lower water table level and reduce freshwater fluxes, leading to severe saltwater intrusion problems in several coastal and metropolitan areas [1–3]. However, water supply is necessary for regional economic development and even for energy production. For instance, renewable sources of energy associated with the salinity gradient can be recovered in coastal areas where freshwater is mixed with saltwater. The techniques to produce electric energy from salinity gradient use the pressure-retarded reverse osmosis process [4] and associated conversion technologies. In addition, also geothermal energy production at low enthalpy should also increase at a rate of 3%–4% in Italy until 2020 [5]. Both geothermal low-enthalpy technology and the pressure-retarded reverse osmosis method require freshwater supplies (i.e., pumping) from coastal aquifers.

Subsequently, the subtraction of appreciable freshwater volumes from coastal aquifers cannot be always avoided and its real impact on groundwater should be adequately investigated. The salinity maps are useful tools for coastal groundwater management and they show how inland advancements of seawater may affect coastal aquifer quality. Chongo et al. [6] carried out an experimental work in Africa to define groundwater salinity variation map within the sedimentary formations of the