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Hydrogeological modeling for sustainable groundwater management under climate change effects for a karstic coastal aquifer (Southern Italy)

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ABSTRACT

Seawater intrusion is a pervasive problem affecting coastal aquifer, where the concentration of population and the increasing water demand creates risks of overexploitation, especially in those areas where is the only resource of drinking and irrigation water. We focus attention on a karst coastal groundwater system effect of an intensive agricultural use. The general purpose of this paper is to prove the capability of numerical models in management of groundwater. In particular for achieve forecast scenarios to evaluate the impacts of climate change on groundwater resources. A large-scale approach was chosen. Qualitative and quantitative groundwater trends from 1930 to 2060 was so defined. Results show an important piezometric decrease and an increment of seawater intrusion and so a deterioration of groundwater resource. For these use requirements different scenarios of pumping are considered for management and mitigation of seawater intrusion effects.

GEOLOGICAL AND HYDROGEOLOGICAL CONTEXT

The Apulian region, with its 800 km of coastline, is the largest coastal karstic aquifer in Italy. In particular, the region is composed of three karst structural domains: Gargano, Murgia and Salento (Figure 1). The Murgia and Salento Mesozoic rocks form a lithological, geological and groundwater continuum but have a different hydrogeological behavior due to different lithofacies, the different degree of fracturing and karst, and to very different boundary conditions (Polemio et al., 2009). From an hydrogeological point of view Salento can be subdivided into five hydrogeological complexes (from the bottom): Limestones, Andrano Calcarenites, Gravina Calcarenites, sub-Apennine clays and Sands. The piezometric gradient is generally low (0.3-0.5% as mean value), with maximum height values lower than 5 m a.s.l.. Deep aquifer is exclusively fed by rainwater infiltration because of scarcity of superficial stream and for the

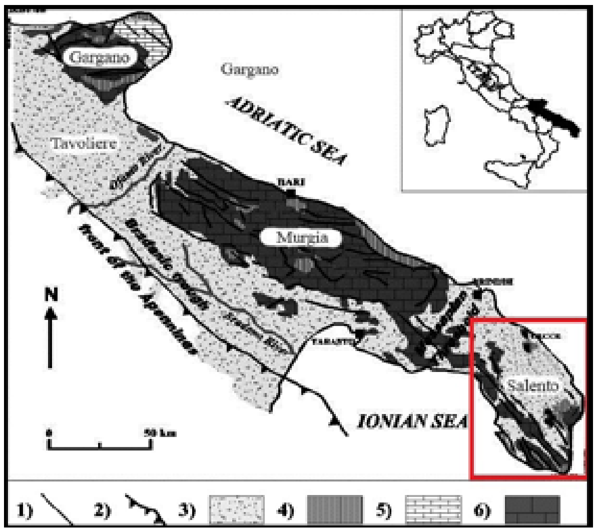

Figure 1. Geological scheme of Apulia. 1 Fault, 2 Front of the Apennines, 3 Recent clastic cover (Pliocene– Pleistocene), 4 Bioclastic carbonate rocks (Paleogene) and calcarenites (Miocene), 5 chert-carbonate rocks (Upper Jurassic- Cretaceous), 6 carbonate platform rocks (Upper Jurassic- Cretaceous). Red Line: study area.

presence of extended surface karst areas that create direct link between rainwater and the deep karst system. Natural discharge is both diffused and concentrated. There are numerous springs located along coastline. A distributed flow along Salento coast was estimated about 56,7 l/s*km (Romanazzi and Polemio, 2013). On the base of these datas conceptual model was achieved (Figure 2).

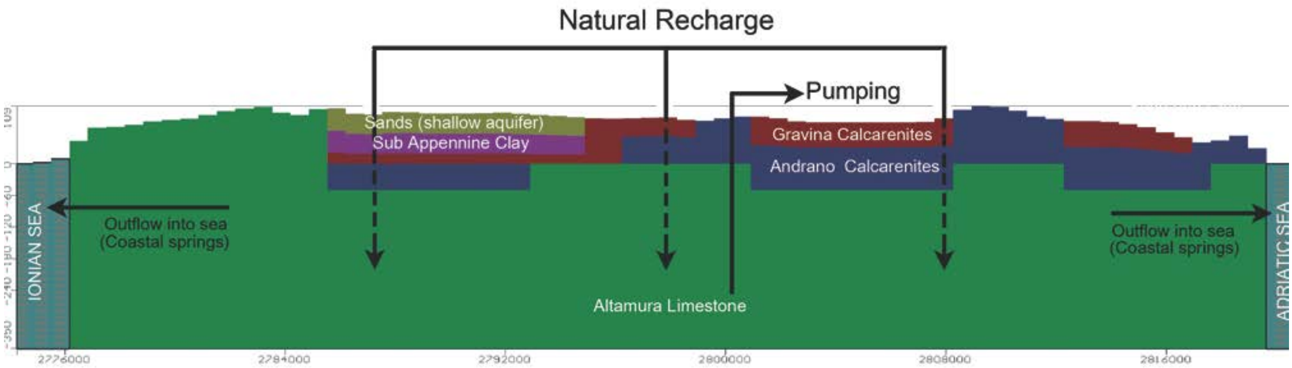

Figure 2. Conceptual model of Salento model area. Generic schematic section W-E.

MODEL DEFINITION, CALIBRATION AND PREDICT SCENARIOS

The numerical codes used were MODFLOW (McDonald and Harbaugh, 1988) and SEAWAT (Guo and Langevin, 2002). The active domain of the study area (active cells) covered approximately 2,300 km^2 with 45,925 cells. Vertically, the area was divided into 12 layers, from 214 to -350 m a.s.l., to allow a good lithological and hydrogeological discretization. Thickness and geometry of layers were defined on the 3D knowledge of hydrogeological complexes. As input, natural recharge, considering the climate change, from 1930 to 2000, was calculated in addition to geological and hydrogeological datas. Trends of agricultural activity, available from 1971 to 2000, by the National Institute of Statistics Data, ISTAT, were evaluated to take account of human activity on the territory, whose vocation for tourism and agriculture accounts for approximately 70% of groundwater resources. A first model representing the natural steady-state condition at thirties years was made and later model was validated with two transient scenarios using 1989 and 2000 experimental datas. The purposes of these implementations are, besides validated model, to supervise and to evaluate the development of groundwater resource in the area, in the last seventy years, or in the period from 1930-2000. The results emphasizes an essential decrease of piezometric level and a development of the intrusion phenomenon of seawater into aquifer (Polemio and Romanazzi, 2012; Romanazzi and Polemio, 2013). Three forecast transient scenarios, referred to 2000-2020, 2020-2040 and 2040-2060, were implemented, on the basis of this calibrated and validated model, with the aim to predicting the evolution of piezometric level and seawater intrusion. We referred for forecast datas of precipitation and temperature to the Giorgi and Lionello model, in relation to the defined “A1B scenario” (Giorgi and Lionello, 2008). This climate forecast model give temperature and precipitation predictions, in reference to 1961-1980, for the period 2001-2100. An average increase of temperature equal to +0.9 ° C was so considered for decade 2001-2020 and equal to +2.4 ° C in the interval 2041-2060. Precipitations, instead, shows a negative change in percentage, compared to the period 1960-80, equal to -3.9%, -5.9% and -9% respectively for 2001-2020, 2021-2040 and 2041-2060. These datas are in agreement with other climate change models presents in literature (Garcia- Ruiz et al., 2011). A new water budget was elaborated for the years 2020, 2040 and 2060. Since in not possible to predict future irrigation discharges, these were left constant and equal to those of the years 2000. The scenarios results shows a general decrease of the piezometric head and a deterioration of water quality caused by seawater intrusion (Romanazzi et al., 2013) (Figure 3).

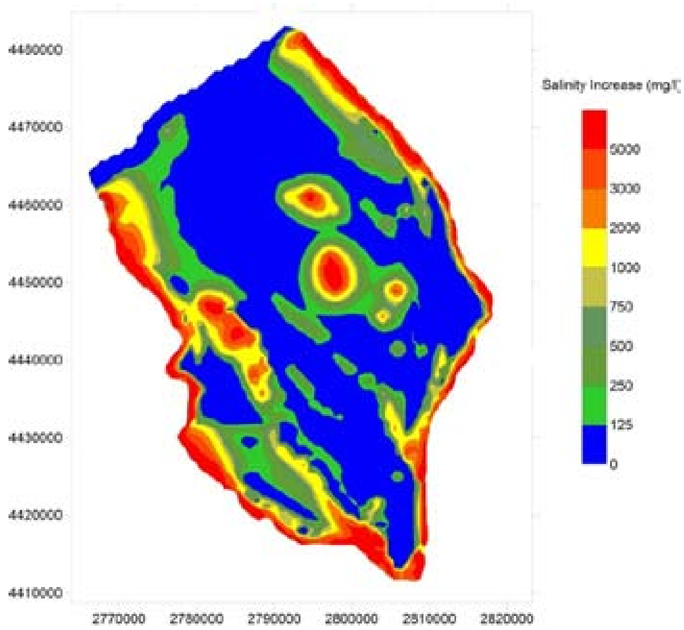

Figure 3. Salinity increase (mg/l) between 1930 and 2060.

MANAGEMENT CRITERIA AND CONCLUSION

That being so, new management tools are essentials. Apulian regional laws tried to regulated groundwater abstraction until 1984. First Regional Water Recovery Plan, called PRA, tried to define a groundwater quality zonation in the Region (Apulia Region, 1982). In this plan new discharges was forbidden in which areas where water quality was lowest due high salinity, especially along coastline. In 2007 Regional Administration promoted the new Water Protection Plan, called PTA (Apulia Region, 2009), on the base of advice of Water Framework Directive,WFD 2000/60 (European Community, 2000). Plan defined two zones for Salento karst aquifer. In the first, located along coast, where is a low quality water, new discharges was forbidden. In the second zone, defined "qualitative and quantitative protection zones", new authorizations are permitted but regulate by some parameters as the depth of well and piezometric and chloride limits values. However both plans do not explain in detail the hydrogeological criteria used to define zones. Based on international (LaMoreaux, 2010; Jiménez-Madrid, 2010) and local studies (Polemio et al., 2009, Polemio et al., 2010) a new management criterion was implemented into the model. To define the zone boundary, a very simple criterion was used: threshold equal to 0.5 g/l between pure fresh groundwater and any type of mixing between fresh and saline groundwater (Polemio et al., 2010). Three zones are so defined. In the first, coinciding with the coastal zone, salinity is always above the threshold, in the second, a transition zone, salinity is function of more parameters, and the third, in the inner area, where salinity value is permanently below the threshold. These three zones was implemented in the model and, keep constant the discharges quantity of 2000 years but with no discharge from coastal zone. In others words, the same pumping was redistributed in the three different areas. A new piezometric and salinity distribution had permitted to study the reaction of the aquifer. This simple proposal show as large scale numerical model can be used for support the management of groundwater resources and subsequent applied for predictive scenarios, especially in those areas where policy of groundwater resource scientifically based is absent.

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