Surface water and groundwater monitoring and numerical modeling of the southern sector of the Massaciuccoli Lake basin (Italy)

RUDY ROSSETTO (*), PAOLO BASILE (*), SILVIA CANNAVÒ (*), CHIARA PISTOCCHI (*), TIZIANA SABBATINI (*), NICOLA SILVESTRI (**) & ENRICO BONARI (*)

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INTRODUCTION AND STUDY AREA SETTING

Investigating the natural system and evaluating a reliable water budget are fundamental and mandatory steps prior to any remedial action development that may impact the water cycle. During a project aimed at defining mitigation schemes to the eutrophication problem, a detailed quantitative surface- and ground-water monitoring of the southern sector of the Massaciuccoli Lake basin was performed. The acquired data were then processed to build a numerical model of the first aquifer.

The Lake of Massaciuccoli (7 km^2 wide and 1.5/2 m deep) and its palustrine nearby areas (about 13 km^2 wide) constitute a residual coastal lacustrine and marshy area. Large part of the basin has been reclaimed since 1930 by means of pumping stations forcing water from the drained areas into the lake. In the study domain two mechanically drained sub-catchments are present: the *Vecchiano* and the *Massaciuccoli Bonifica* (Fig. 1).

An update review of the literature was performed and several stratigraphical data analysed to provide a hydrostratigraphical simplified conceptual model. The main hydrostratigraphic unit is defined by sand deposits which constitute a 30 to 40 m thick superficial aquifer on the west side, and pinching out on the eastern margin while passing to sandy to clayey silt unit. These two units are overlain by recent deposits (few meters thick) showing a North-South trend moving from the alluvial fan deposits (silty to clayey sands) of the Serchio River to peaty clay and then peat. In terms of hydrological boundaries, the investigated domain is bordered by carbonate to arenaceous reliefs on the east and by a potentiometric high in the sandy coastal shallow aquifer on the west. South and North of the domain, the Serchio River and the Lake Massaciuccoli water body respectively are hydraulically connected with the superficial aquifer. Hydrogeochemical analysis confirmed the hypothesis on the conceptual model (PISTOCCHI *et alii*, 2010).

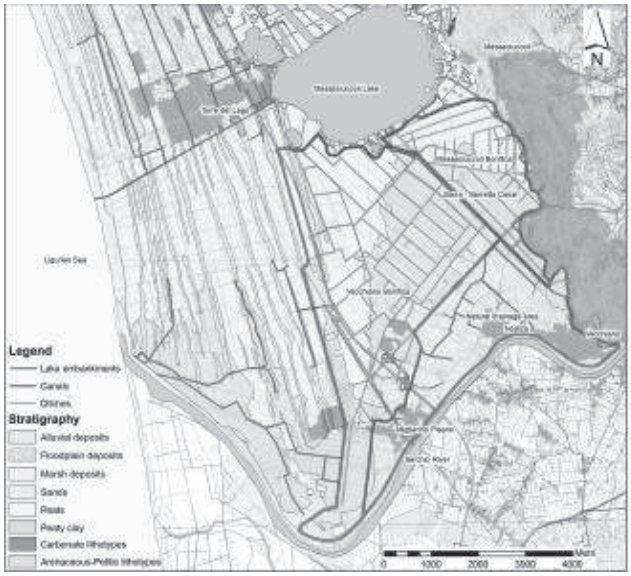

Fig. 1 – Study area setting.

SURFACE AND GROUNDWATER MONITORING AND THE GROUNDWATER NUMERICAL MODEL

Surface water discharges of several drains were monitored monthly to determine baseflow. Measurements were performed by means of an acoustic digital current meter (OTT ADC; OTT MESSTECHNIK GMBH, 2008) due to low flow velocities. At the same time groundwater head in the superficial aquifer was monitored during several campaign in order to get a deeper insight on the boundary conditions. On the other hand, this kind of activities showed that traditional monitoring in reclaimed land area is not appropriate to represent the groundwater flow field, because of the presence of several drains, which would require a large number of monitoring wells. Anyway, they confirm that recharge to the aquifer occurs also by means of lake seepage, and from the sand dune aquifer to the *Vecchiano Bonifica*, while the carbonate relief aquifer discharges into the *Massaciuccoli Bonifica*.

(*) Land Lab - Scuola Superiore Sant'Anna, r.rossetto@sssup.it

(**) Dipartimento di Agronomia e Gestione dell'Agroecosistema – Università degli Studi di Pisa, nsilve@agr.unipi.it

Then, in order to define the groundwater flow field and to estimate baseflow to the drainage ditches a groundwater numerical model by means of the MODFLOW-2000 (HARBAUGH *et alii*, 2000) code was implemented. A transient simulation, using time steps ranging 2.5 to 5 days, was performed and calibrated for the period July 2008- December 24 2009. The conceptual model was translated into a numerical one by means of a grid of 11.9x10.6 km, with 25x25 m cells, and three layers, the first one representing superficial deposits while the second and third one the sandy aquifer. Values for hydraulic conductivities and storage were derived both from site-specific tests, previous studies and literature data. In terms of boundary conditions, the lake, the sea and the Serchio River were represented using a time-variant Dirichlet condition, while recharge due to meteoric precipitation and inflow from the eastern carbonate aquifer were simulated by means of a Neumann's condition. The drainage network as well as the canals used for irrigation purposes during the summer period were reproduced using a Cauchy boundary. Initial conditions were derived by a steady-state simulation calibrated on low-flow conditions. Calibration was performed under steady and transient state by means of automated and trial and error methods using both heads and surface water flow measurements. Having several different sets of measurements and two kind of variables to perform calibration helped in constraining uncertain parameters and therefore the solution of the flow field.

The implemented model allows to define the groundwater flow field (Fig. 2), to estimate the baseflow volume drained by the *Vecchiano* and *Massaciuccoli Bonifica*, and to quantify the relative groundwater contribution to these sub-catchments by the adjoining areas. These data, compared to the overall water budget (PISTOCCHI *et alii*, 2010), shows that nearly 80% of the water raised by the pumping stations from the two *Bonifica* into the lake is constituted by groundwater drained form the superficial aquifer. Hence, the analysis of the transfer processes of pollutants into the lake due to the reclaimed land shall take in account both transport processes in the aquifer and physico-chemical processes in the hyporheyc zone.

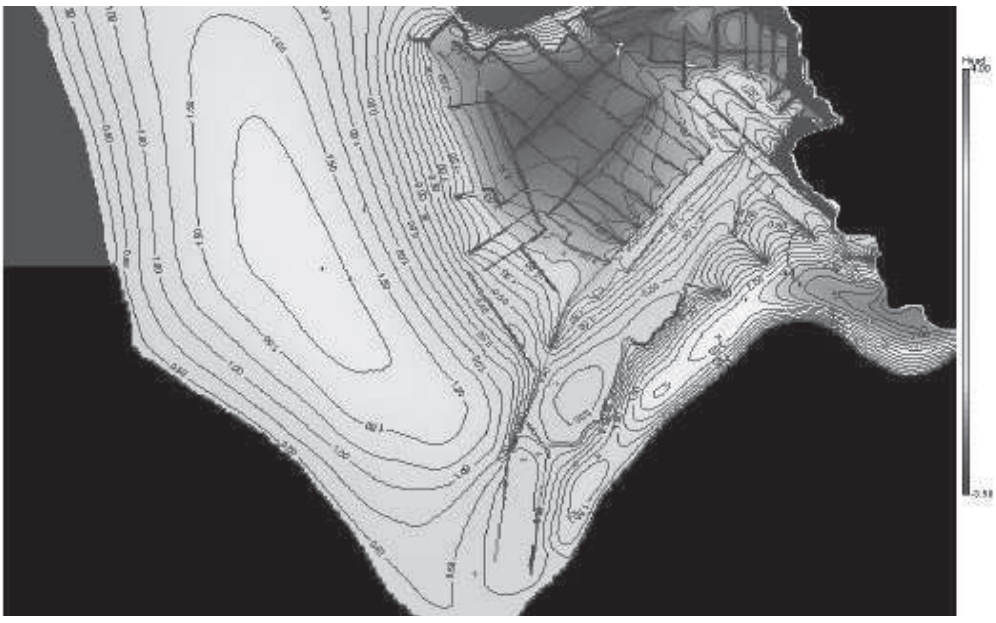

Fig. 2 – Simulated head in the investigated domain at the end of the spring period 2009.

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