Dam–aquifer multisystem modelling for the Wadi Merguellil basin, Tunisia

MOHAMEDOU OULD BABA SY & MUSTAPHA BESBES

Laboratoire d'hydraulique, Ecole nationale d'Ingénieurs de Tunis, BP 37 Le Belvedère – 1002 Tunis, Tunisia

e-mail: babasy.mohamed@enit.rnu.tn

Abstract The Merguellil basin (1200 km^2) in Tunisia consists of four mutually dependent groundwater systems including that of Aïn Beïdha, which is closely related in the north to Wadi Merguellil, and to the south to Wadi Zeroud. The building and water filling of dams on these two wadis have modified the form of their relationship with the aquifer. Clear rises of piezometric levels are observed beside the two dams. These rises of piezometric levels are simulated by means of a model representing the aquifer system and the two dams which constitute the boundary conditions of the model.

Key words abstraction; aquifer; dam; dam–aquifer modelling; groundwater recharge; piezometric levels; Tunisia; wells

INTRODUCTION

The Merguellil basin groundwater system (Tunisia) is made up of the Bou Hafna, Haffouz, Chérichira and Aïn Beïdha systems. The whole system is controlled by the Merguellil Wadi that recharges groundwater in the upstream part and drains it in the downstream part. This flow regime changed at the beginning of the 1970s when groundwater abstraction rapidly increased leading to the present situation of controlled but increasingly intensive exploitation of groundwater. This situation convinced the decision makers of the need for a simulation model of the system. A simulation model was recently developed to represent the aquifer system of Bou Hafna from which the majority of the abstractions are made (Gribaa, 1997). In addition, we have developed a model representing the Aïn Beïdha aquifer to enable more precise study of the effect of water filling the El Haouareb dam on the Merguellil Wadi in north, and the Sidi Saâd dam on the Zeroud Wadi which is the southern limit of the aquifer system.

THE AVAILABLE DATA

Borehole data

Borehole data were used to establish lithostratigraphic correlations and maps of the bottom and top of the aquifers. This allowed us to identify the four interconnected aquifer systems and also contributed to the understanding of the hydrodynamics of the system. These data also made it possible to establish maps of the transmissivity distribution and storage coefficient, which were used to build the simulation model. These parameters were obtained by interpretation of pumping tests made using the Theïs method (Besbes, 1967).

Piezometric data

The piezometric data relate to the whole Merguellil basin system. The network for monitoring the piezometric levels of the phreatic water table consists of 16 observation wells, of which nine have a series of 25 years of nearly complete measurements (1973 to 1997). For the deeper groundwater system, 26 measurement locations were available (including 10 piezometers and 16 dug wells), of which 10 locations have a nearly complete data series for 1973 to 1997. The average rainfall in the basin is 350 mm year^{-1} (Besbes, 1967). Figure 1 shows annual rainfall variability in Haffouz. Total groundwater recharge in the basin is estimated at approximately 75 mm year^{-1}, while total abstraction ranges from 30 to 68 mm year^{-1} for the deeper groundwater system (Fig. 2).

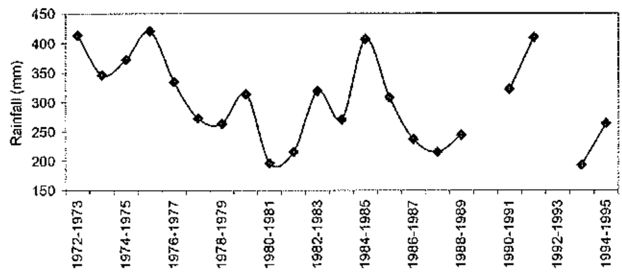

Fig. 1 Rainfall variability at Haffouz, 1972–1995.

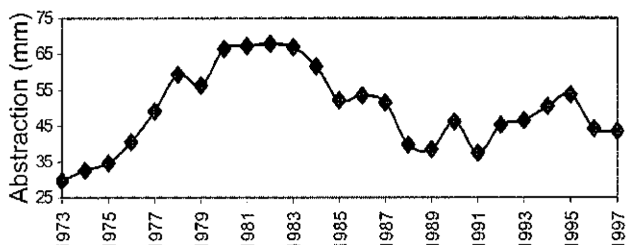

Fig. 2 Evolution abstraction from the deeper groundwater system, 1973–1997.

Pumping data

The number of dug wells was 150 in 1974, together abstracting 1 million m^3 year^{-1}. This number had increased to 750 wells by 1985, abstracting 5 million m^3 year^{-1} in total. In addition, the number of deep wells increased from 20 in 1973, abstracting 10 million m^3 year^{-1}, to 50 in 1997 abstracting 16 million m^3 year^{-1}.

METHODOLOGY

As a first step, we constructed a simulation model of the Aïn Beïdha aquifer system. The simulation results relate to this system. We studied the interaction between the dam and the water table by using data on the level of water stored in the dam. The observed piezometric levels of certain wells show an increase following the start of the dam operation, for the dam of El Haouareb in August 1989, and for the dam of Sidi Saâd in December 1981. These dams contributed water to the aquifer, raising the water table. In addition, the outcrops of the four-aquifer systems were precisely mapped, so that the areas of potential recharge, permeable outcrops, infiltrating streams and "useful" basin-slopes could be identified. We analysed the precipitation in the recharge areas and also analysed the runoff of the potentially infiltrating streams.

The model used is the software MULTIC, developed at the National Engineering School of Tunis (Besbes *et al.*, 1991). This model resolves the diffusivity equation:

$$\frac{\partial}{\partial x}\left(T_{xx}\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(T_{yy}\frac{\partial h}{\partial y}\right)=S\frac{\partial h}{\partial t}+q$$

where T and S are respectively the transmissivity and the storage coefficient; h is the hydraulic head; and q is the abstraction or the recharge per surface unity.

This equation is integrated in a domain divided into regular square cells. The spatial parameters are approximated by the finite difference method, while the temporal approximation is realized with the help of a pure implicit scheme. The equations used for this are numerically resolved by the Gauss-Seidel method with surrelaxation per point. Three boundary conditions are integrated in the model: constant head cell, active variable head cell and inactive cell (no flow takes place within the cell).

The model is calibrated by comparing the observed and the calculated heads. Transmissivity data were available for steady-state calibration, and storage coefficients and surface water levels in the dam for transient state calibration.

RESULTS

The simulation results relate to the Aïn Beïdha aquifer system over the period 1973 to 1997. As the natural recharge undergoes variation according to the climatic conditions, we studied the historical behaviour of the water table compared to the steady state. The piezometric levels of the deep water table of Aïn Beïdha are not reproduced in the calibration due to the lack of a series of representative measurements. As for the phreatic water table, the nine wells with the longest series of measurements were selected as control points. The simulation results indicate that, downstream of the basin of Ain Beïdha, the piezometric levels show a continuous fall with time before exhibiting a remarkable recovery from 1989 onwards, at which date water filled the El Haouareb dam (Fig. 3). This increasing of the piezometric levels is accentuated by the strong rains of the year 1990. The pre-1989 decreasing piezometric levels are explained by the fact that these wells are located in the most exploited zones of the aquifer. The wells located in the south of the basin show a clear rise of piezometric levels since 1982 following the water level rise in the Sidi Saâd dam in December 1981 (Fig. 4) (Baba Sy & Besbes, 2000).

In the near future, an integrated model will be constructed to simulate the entire four-aquifer system, because the four aquifers are closely connected. We will then focus on the phenomena of the overexploited Bou Hafna aquifer system; it is recharged

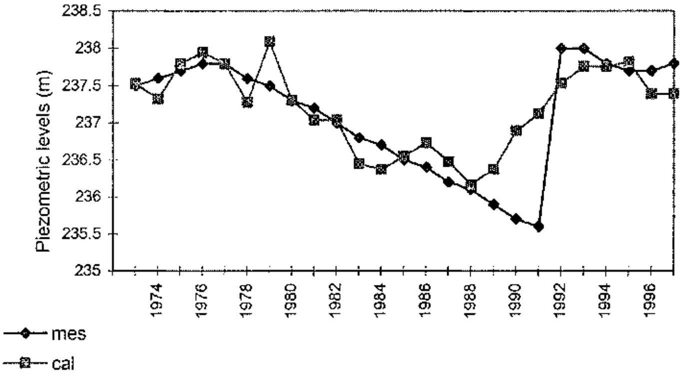

Fig. 3 Piezometric levels beside the El Haouareb dam.

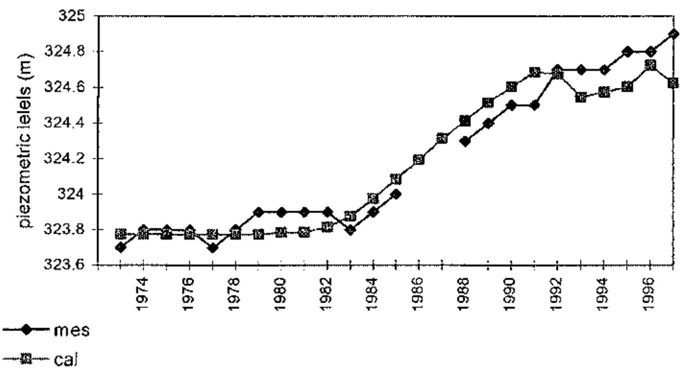

Fig. 4 Piezometric levels beside the Sidi Saâd dam

with approximately 7 million m^3 $year^{-1}$ (Besbes, 1967), but 12 million m^3 was abstracted in 1997 (Gribaa, 1997). The decrease of piezometric levels observed here tend to spread throughout the whole system. We will thus simulate, the impact of the long-term abstraction regime on the basic groundwater flow towards the El Haouareb dam.

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