Impact of Climate Change on Water Resources in Seyhan River Basin

Mathematical Modeling of the Groundwater System: Results of the First Run

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1. Introduction

The Adana alluvial plain, constitutes the major groundwater resources in the Seyhan River Basin (Figure 1). Following the hydrogeological characterization of the Adana alluvial plain, the conceptual model was transferred to the mathematical models. Sea water intrusion was also considered in the conceptual model. Therefore, in addition to the groundwater flow model, the seawater intrusion was also transferred to a mathematical model and run together with the groundwater flow model. MODFLOW (MMcDonald & Harbaugh, 1998) was used to simulate the groundwater flow while the sea water intrusion was simulated by SEAWAT-2000 (Langevin, et al., 2003), integrated with MODFLOW.

Following calibration runs, the models were run to simulate the groundwater flow and solute transport (sea water intrusion) for two climate change scenarios. The vulnerability of the plain aquifer system was then evaluated and interpreted in terms of ground water potential and quality.

2. Hydrogeological Conceptual Model

The Berdan-Tarsus river and Ceyhan River borders the study area from the west and east respectively. The plain aquifer covers an area of about 2271 km^2, extending between these borders. Water demand for irrigation in the plain is supplied to a great extent from the Seyhan Dam Lake that borders the study area from the north. Therefore, only a certain number of boreholes were drilled, most of which are located in the northern part of the plain to supply water to the Adana Metropolitan city. However, after drip-irrigation system became attractive to the farmers in the plain, a few boreholes are drilled in the southern part of the plain. The data of these boreholes were used in conceptualizing the groundwater system.

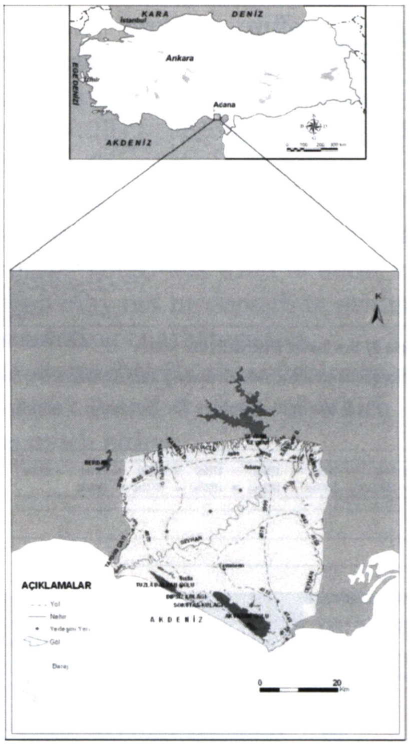


Figure 1 Location map of the study area

The geohydrologic characterization of the plain aquifer system was based upon the 203 well logs. Depth of boreholes drilled at the northern part does not exceed 100 m., whereas the boreholes at the south are deeper; 363 m. the deepest. The

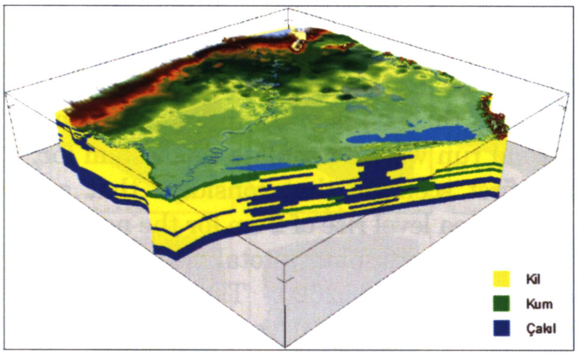


Figure 2 3-D distribution of lithologic units in plain

lithological configuration of the plain aquifer system is depicted in Figure 2. The Tarsus-Berdan river that borders the area from the west, flows over a thick clay (impervious) layer. Similarly the Ceyhan River flows over a thin sandy layer underlied by again a thick clayey layer. The northern part of the plain is covered by a succession of gravel-clay-gravel.

Detailed study of the well logs suggests that it is difficult to distinguish more than one aquifers, but instead, it is more realistic to consider one heterogeneous aquifer with vertical and horizontal interfingering layers of pervious and impervious deposits; which is also supported by the type of the depositional environment. The 3-D distribution of the clay, sand and gravel layers were transferred to the mathematical model assigning a distinctive hydraulic coefficient for each. The aquifer is recharged through direct rainfall onto the areas where coarse deposits are exposed, from seepage from the Seyhan River where the bed is

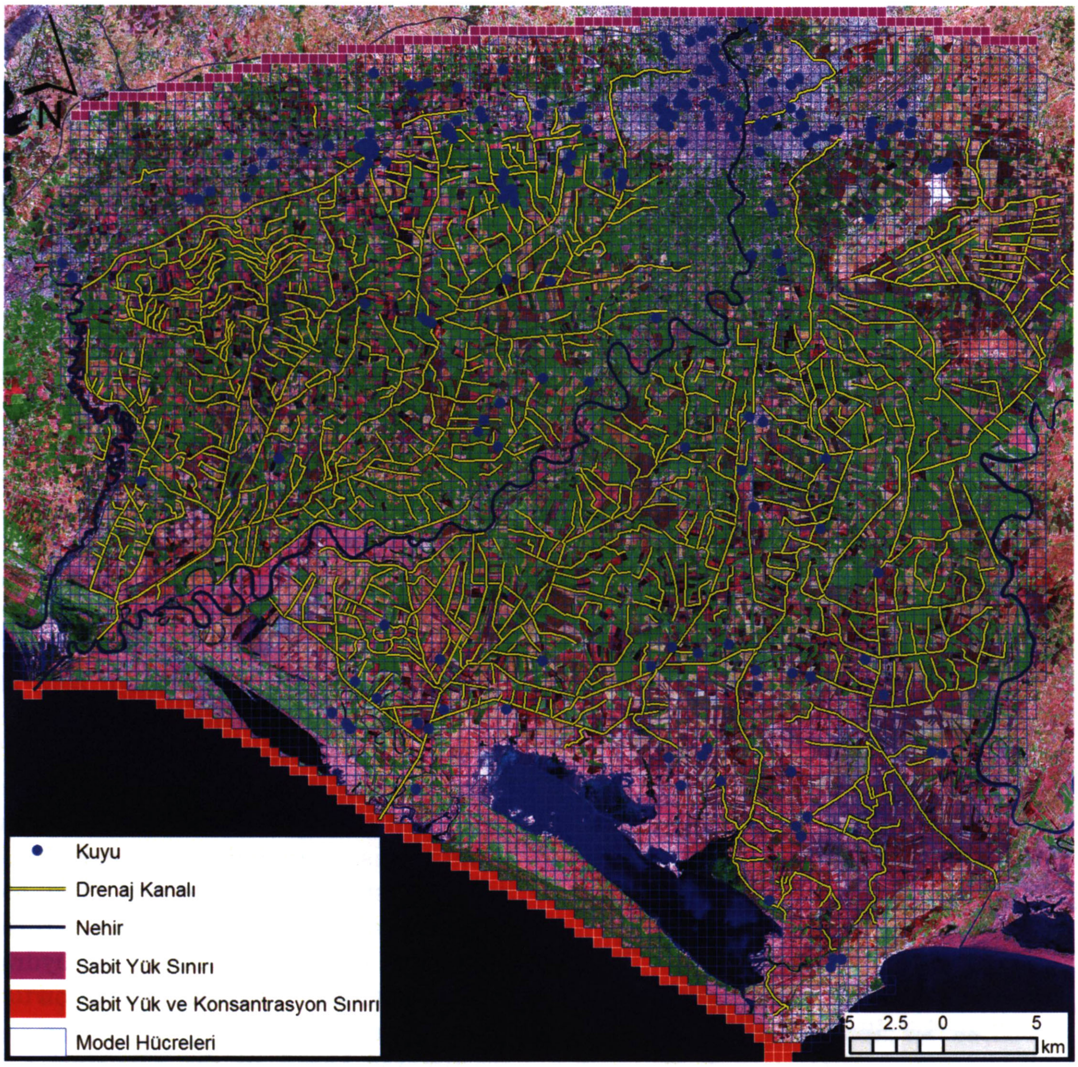


Figure 3 Grid mesh and boundary conditions in the modeled area

composed of pervious material and through inflow the northern boundary. Because the amount of the inflow through the northern boundary is difficult to predict and any prediction would associate significant uncertainty, the boundary condition was defined based upon the groundwater level measurements in the boreholes close to this boundary. This provided that recharge through this boundary is computed by the model based on the gradient changes.

Discharge of the aquifer occurs as the outflow into the sea, effluent flow to the Seyhan River where hydrogeologic conditions are appropriate, and as groundwater abstraction through wells and drainage canals.

3. Mathematical Model of the Adana Plain Aquifer

The conceptual model outlined above was transferred to a finite difference grid of 500x500 m composing 250860 cells in total (Figure 3). The third dimension was taken between elevations of 20 m. above and 320 m below sea level. 20 model layers of 20 m thickness each were defined to represent the vertical dimension. The model was run for steady state conditions first to achieve calibration. The simulation was performed for three periods starting from 1990. The first run was performed to simulate the present conditions for 10 years, thus having the conditions of the year 2000 computed by the model. The result of this run is given in Figure 4. The second run was to simulate the system for the first scenario that considers that an annual sea level rise of 2 cm for the next 20 years, thus attaining a total rise of 40 cm at the end of 2020. The third run simulated another 50 years. The rate of sea level rise was increased for this period. And the total rise at the end of the period was 80 cm.

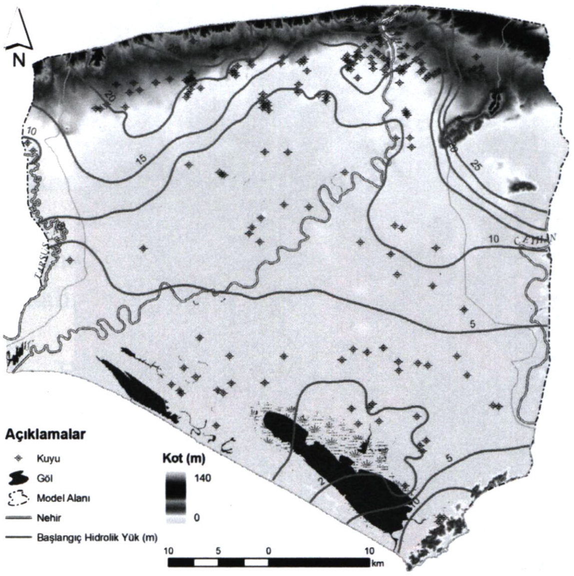
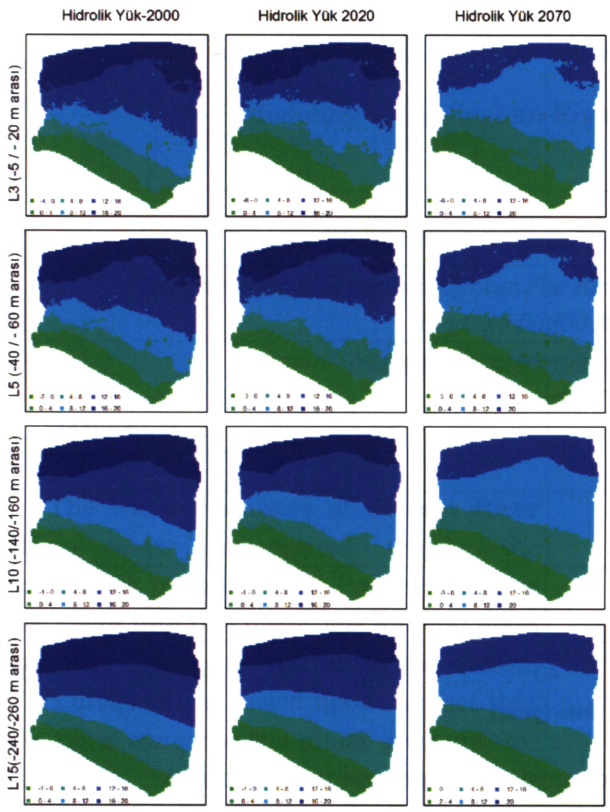


Figure 4 Head distribution from steady-state simulation for 2000

The boundary condition at the south where the aquifer is in contact with the sea was taken as "constant head-concentration boundary" for the first 10 years; whereas this boundary was changed to "variable head-concentration boundary" during the second and third periods where the system is affected by the climate change. The concentration of the sea water was taken as 19200 mg/l of Cl from chemical analysis of the sea water.

The constant-head at the northern part was taken as 20 m. on average. No concentration was given at this boundary. The impact of the climate change was reflected by decreasing the head by 10% to 18 m for the first 20 years, and to 15 m for third period. The recharge rate was defined based upon the excess water calculated from the hydrometeorologic data. Regarding the time-scale of the study, recharge was input on annual basis to the model. The impact of the climate change was reflected by decreasing the rate of recharge by 20 % for the period 2000-2020 and by 40% for the period 2020-2070. Uniform recharge over the plain was assumed for this preliminary run. The water depth at Seyhan River was taken 10 cm on the average. Discharge as outflow to the sea is computed by the model taking the constant-head approach. The model also calculates discharges through drainage canals, considering the hydraulic conductivities, bottom elevation and hydraulic gradient. Abstraction was estimated based on the assumption that demand for groundwater will increase by 20% during the third period.



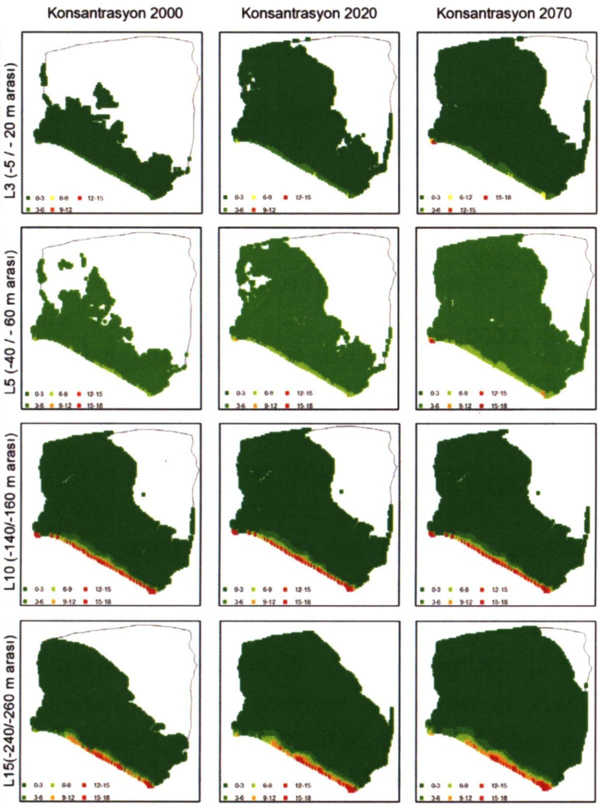


Figure 5 Head distribution at different layers after simulation the climate change (2000, 2020 &2070)

Figure 6 Chloride concentration distribution at different layers after simulation the climate change (2000, 2020 &2070)

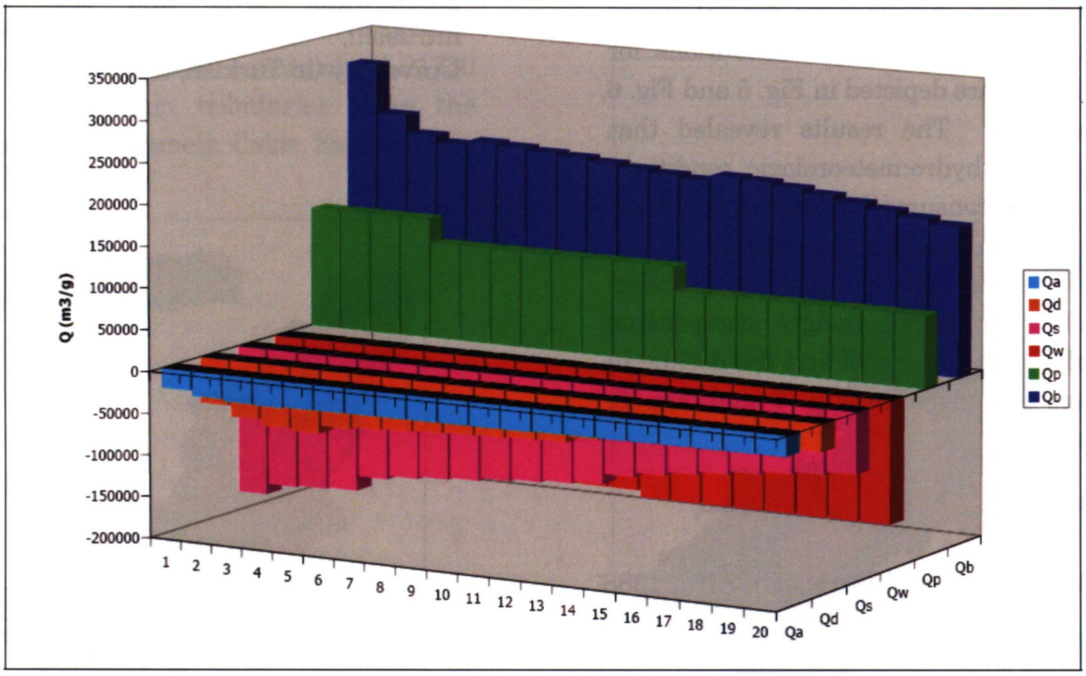


Figure 7 Components of the water budget calculated by the model (Qb: inflow from the northern border, Qp: recharge from precipitation, Qw: abstraction by wells, Qs: outflow to the sea, Qd: drainage by drainage canal, Qa: effluent flow to Seyhan river)

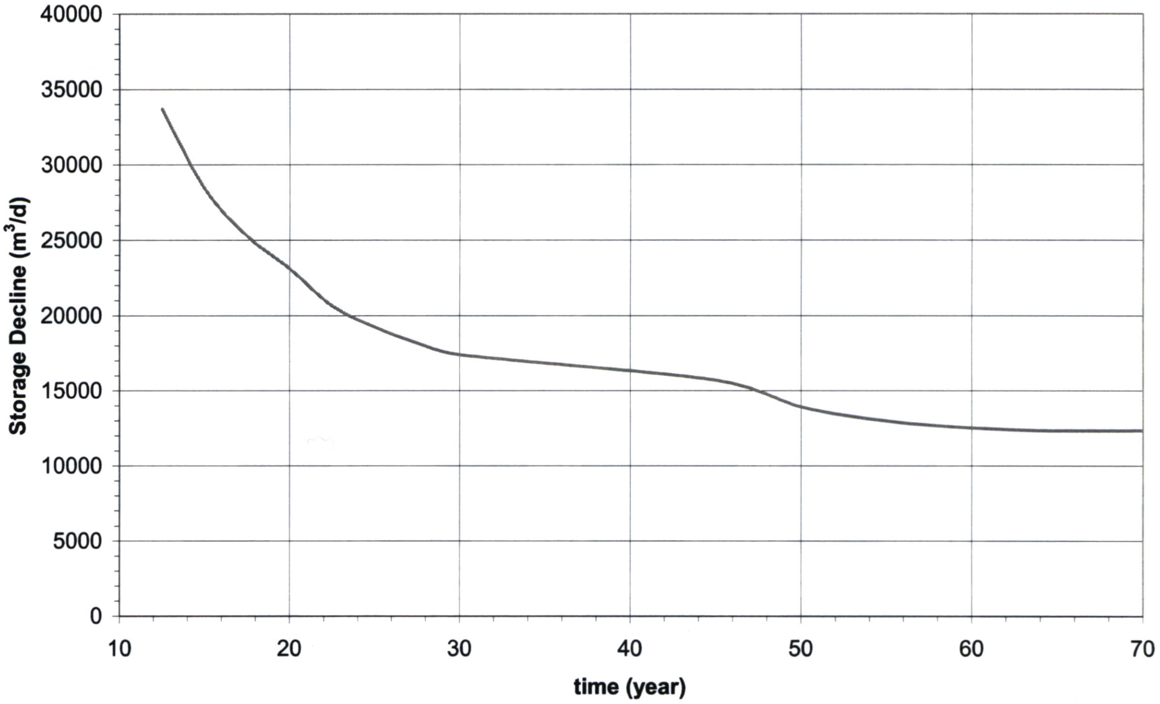


Figure 8 The impact of the climate change on the ground water storage

4. Results

Simulations described above produced results in the form of head and concentration distributions for 80 years. Head and concentration distributions for some years are depicted in Fig. 5 and Fig. 6, respectively. The results revealed that changes in hydro-meteorologic conditions and water consumption affects the head distribution significantly. Similarly, sea water intrusion will pose a problem. Finally the water budget components calculated by the model and the decline in storage are given in Fig. 7 and Fig. 8, respectively.

5. References

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