Seawater Intrusion in Coastal Aquifers at Two Sites in Turkey

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Abstract

Along some parts of the Mediterranean Coast of Turkey, groundwater obtained from coastal aquifers is an important source of water that supplements the use of surface water for municipal, industrial, and agricultural use. Along the coastline, alluvial deposits that consist of a heterogeneous mixture of gravel, sand, silt, clay, and sandy clay extend to a depth of 100 m or more. These unconsolidated materials generally are bounded at the seacoast by the Mediterranean Sea and inland by outcrops of limestone that form the Taurus Mountains farther inland. In this investigation, aquifer systems at Silifke and Mersin in south-central Turkey were characterized, and groundwater quality for these locations was compared and contrasted. At Silifke, the alluvial deposits form the Goksu Delta, in which chloride concentrations increase from less than 100 mg/L in inland areas to more than 2,200 mg/L near the seacoast, and the chemical composition of the water in the delta varies from $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$ type water in the inland areas to NaCl type water near the coast. Overpumping of the groundwater system at Silifke has resulted in saltwater intrusion and has limited the usefulness of this aquifer. At Mersin, which is approximately 85 km east of Silifke, the productive Coastal Aquifer and the less productive Hillside Aquifer form a groundwater system along the seacoast and in the adjacent hillside of the Taurus Mountains, respectively. In this area, most of the groundwater belongs to the $Ca(HCO_3)_2$ facies, although $Mg(HCO_3)_2$, $NaHCO_3$, NaCl, and $CaSO_4$ type waters were also observed. According to the assessment of the chloride content, some of the groundwater in this area has been affected by sea water intrusion.

Introduction

Along some parts of the Mediterranean Coast of Turkey, groundwater obtained from the coastal alluvium or adjacent karstified limestone aquifers is an important source of water that supplements the use of surface water for municipal, industrial, and agricultural use. Along the coastline, alluvial deposits that consist of a heterogeneous mixture of gravel, sand, silt, clay, and sandy clay extend to a depth of 100 m or more. These unconsolidated materials generally are bounded at the seacoast by the Mediterranean Sea and inland by outcrops of limestone that form the Taurus Mountains

farther inland. In this investigation, aquifer systems at Silifke and Mersin in south-central Turkey (see Figure 1) were characterized, and groundwater quality for these locations was compared and contrasted.

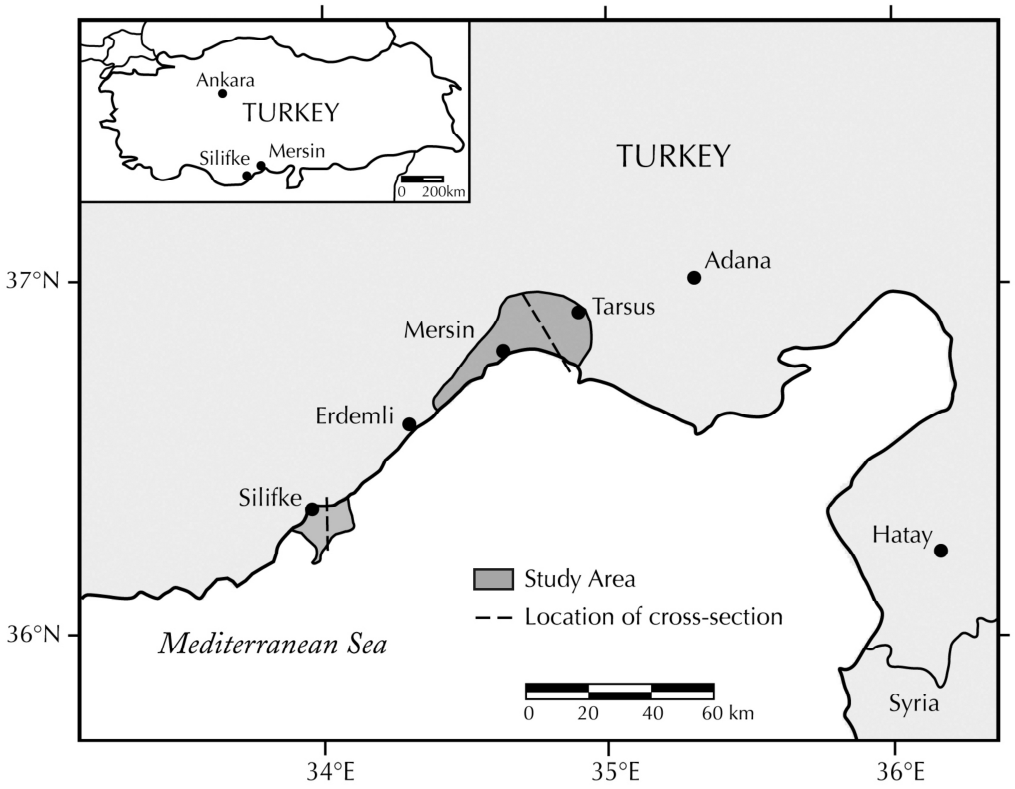

Figure 1. Location of Study Areas at Silifke and Mersin

Hydrogeology of the Goksu Delta

At Silifke, alluvial deposits from the Goksu River have formed the Goksu Delta, which has an area of approximately 150 km^2 between 36° 15' and 36° 25' N latitude and 33° 55' and 34° 05' E longitude (Motz et al, 2005). The alluvium extends to a maximum depth of approximately 500 to 700 m below land surface (see Figure 2). In some parts of the delta, a relatively low permeability clay unit, which extends from near land surface to depths of approximately 20 to 30 m, confines the underlying sediments, in which the more permeable, hydraulically-connected coarse-grained materials function as aquifer units separated by relatively thin clay layers. Conceptually, the aquifer system in the delta consists of the deeper units in which groundwater occurs under artesian, or confined, conditions and shallower units that extend to land surface and contain the water table. Recharge occurs by means of infiltration of river water at the top of the delta where coarse-grained sediments occur and by inflow from the adjacent and underlying karst limestone formations that are recharged by rain and snowmelt in the bordering mountains. Recharge also includes net recharge to the water table, which is a function of rainfall, irrigation, surface-water runoff, and evapotranspiration, and saltwater inflow at depth along the coastal

boundaries of the delta. Discharge from the aquifer system occurs by means of outflow into the lower reaches of the Goksu River, outflow into lakes and drains in the delta, and by means of pumpage from irrigation and drinking-water supply wells. Discharge also occurs along the coastal boundaries.

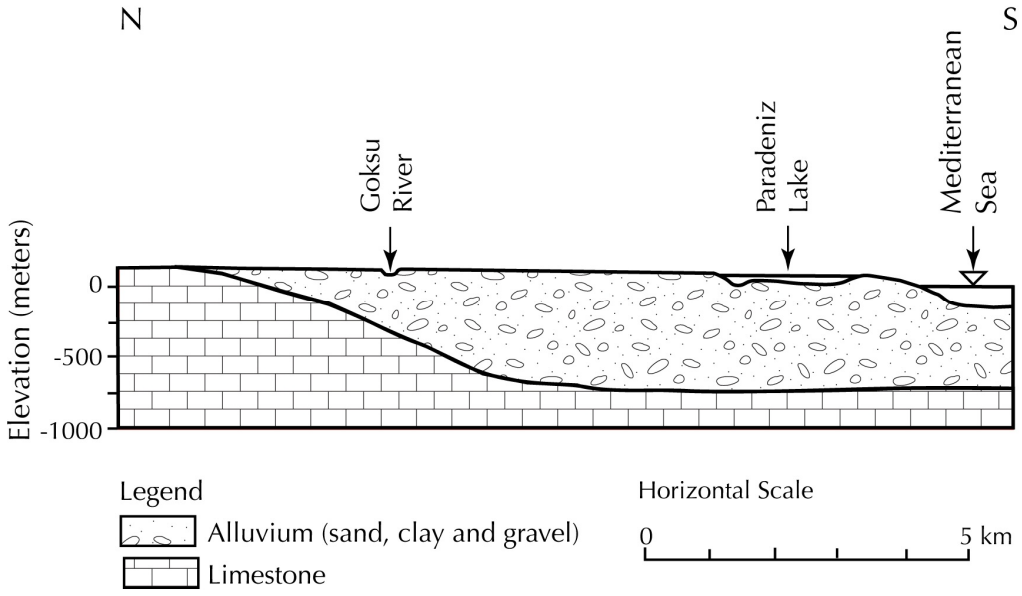

Figure 2. Hydrogeologic Cross-Section in the Goksu Delta at Silifke

Groundwater Chemistry in the Goksu Delta

Thirty-five deep wells, which have depths ranging from approximately 8 to 130 m, were located and sampled during 1999, 2001, and/or 2002. Fourteen groundwater samples were collected from the deep wells in 1999, 16 samples in 2001, and 23 samples in 2002 for a total of 53 samples, and analyses were performed for total dissolved solids, specific electrical conductance, and major cations and anions. The results of the water-quality sampling indicate that chloride concentrations increase from less than 100 mg/L in inland areas to more than 2,200 mg/L near the seacoast and that the groundwater is of the $Ca(HCO_3)_2$, $Mg(HCO_3)_2$, $NaHCO_3$, and NaCl facies (see Figure 3). The $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$ facies occur in the northern part of the Goksu Delta, indicating the presence of a freshwater zone recharged by water from the Goksu River and/or the adjacent limestone formations (see Figure 4). The NaCl facies occurs in the southern and eastern parts of the delta, indicating that a saltwater intrusion zone occurs adjacent to the Mediterranean Sea. The $NaHCO_3$ facies indicates that a freshening zone (Appelo and Postma, 2005) occurs between the freshwater and saltwater intrusion zones.

Hydrogeology of the Coastal and Hillside Aquifers at Mersin

At Mersin, the study area of approximately 800 km^2 lies between 36° 38' and 37° 00' N latitude and 34° 20' and 35° 00' E longitude. The groundwater system consists of

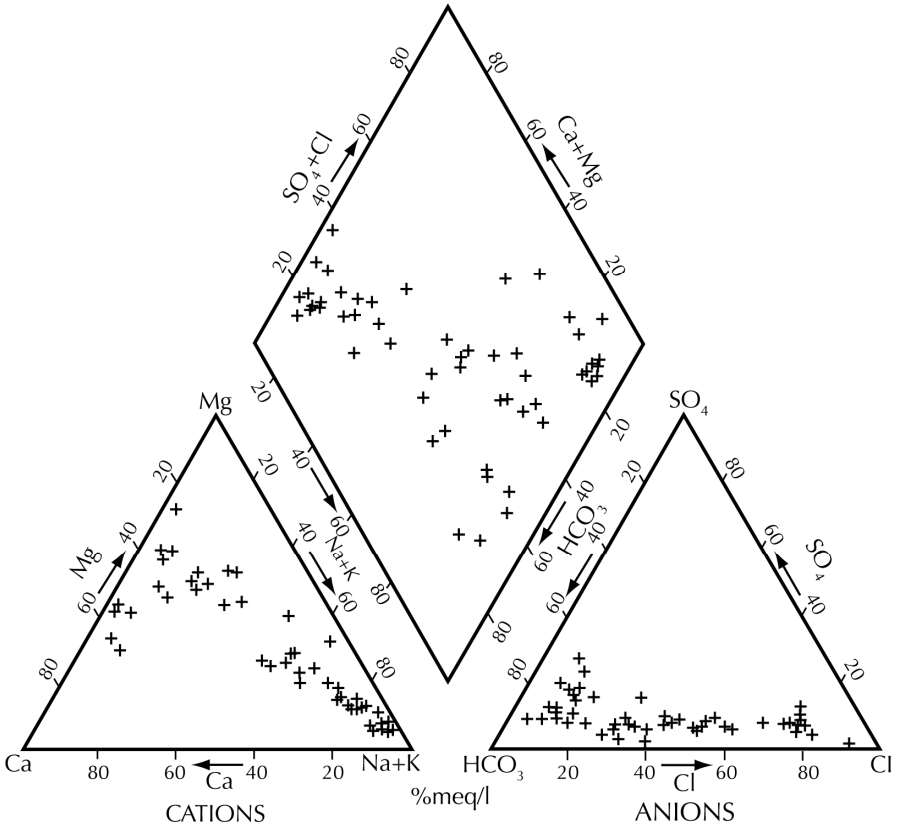

Figure 3. Piper Diagram for Goksu Delta Groundwater Samples

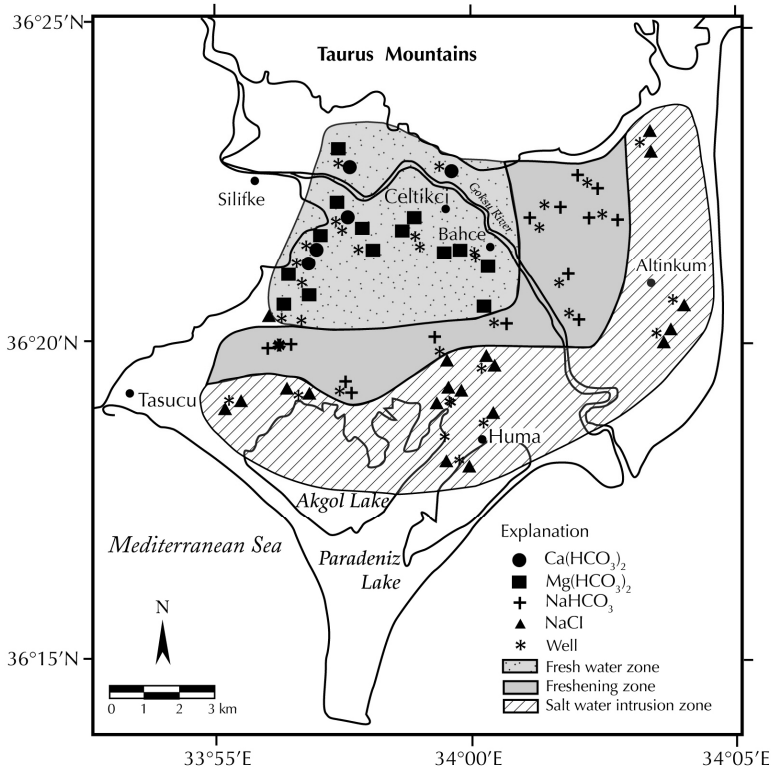

Figure 4. Hydrochemical Facies in the Goksu Delta Aquifer

the productive Coastal Aquifer along the seacoast and less productive Hillside Aquifer beneath the adjacent hillside of the Taurus Mountains. The Coastal Aquifer, with decreasing surface area from east to west, is comprised of Neogene sediments of a fan-delta type alluvial deposition system. The Hillside Aquifer generally is comprised of the intercalation of limestone, sandstone, claystone, siltstone, marl, and conglomerate of Neogene age. These formations are underlain by Mesozoic carbonates of the Taurus Mountains (see Figure 5). Because of the complex distribution of lithologic units, it is very difficult to construct a conceptual model of the hydrogeologic system. Accordingly, in order to develop a conceptual model, environmental isotope data were used. The stable isotope data indicate a wider recharge area altitude distribution of the Coastal Aquifer compared to that of the Hillside Aquifer. Tritium isotope data indicate that the groundwater in the Coastal Aquifer has a longer residence time than the groundwater in the Hillside Aquifer. Part of the recharge to the Coastal Aquifer is from the greater elevations of the Taurus Mountains, and recharge to the Hillside Aquifer is supplied mostly from local precipitation (Hatipoglu, 2004).

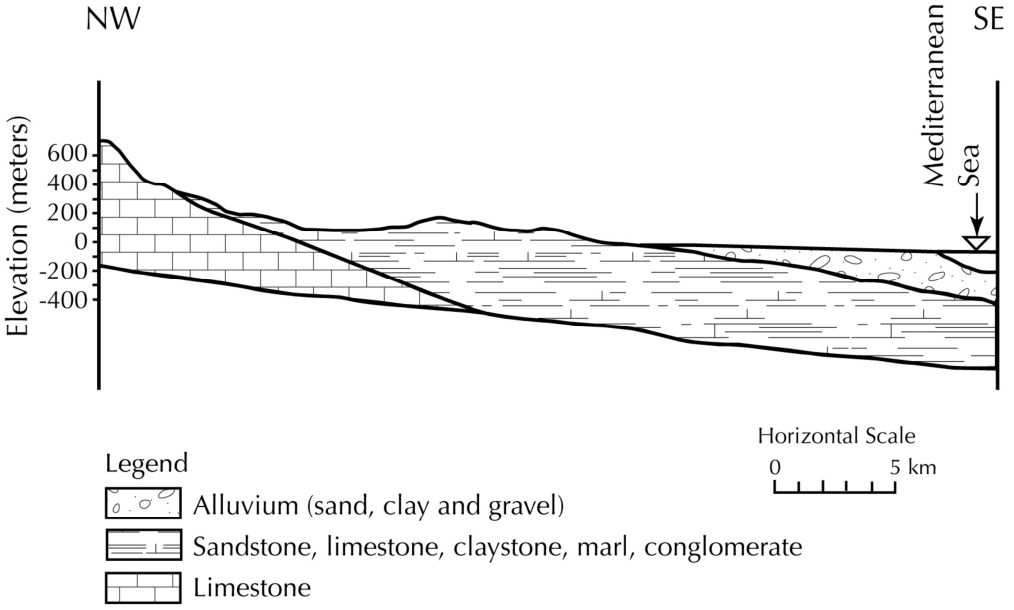

Figure 5. Hydrogeologic Cross-Section at Mersin

Groundwater Chemistry in the Coastal and Hillside Aquifers in Mersin

The groundwater of the Mersin-Tarsus Coastal and Hillside Aquifers extending between Berdan and Karakuz Streams was investigated by means of in-situ measurements and chemical analyses during 2001, 2002, and 2003 and isotope analyses during 2003. Specific electric conductivity (EC), pH, temperature, and dissolved oxygen were measured at the time of sampling. The groundwater EC, pH, and temperature were found to range between 385-6,890 microS/cm, 6.4-8.6, and 20-26 °C, respectively. In two hot water wells, EC, pH, and the temperature were between 10,900-12,000 microS/cm, 7.32-7.59, and 38-40°C, respectively. Samples

were analysed for major and minor cations and anions, nutrients, and metals. Chemical groundwater types of the study area were distinguished by their position on a Piper diagram (see Figure 6). Most of the groundwater samples belong to the $Ca(HCO_3)_2$ facies, although $Mg(HCO_3)_2$, $NaHCO_3$, NaCl, and $CaSO_4$ type waters were also observed. The $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$ facies represent a freshwater zone that is prevalent in the northern higher elevation part, western coastal part, and in the vicinity of Delicay Stream. The NaCl facies indicates that a saltwater intrusion zone occurs in the southeastern parts of the Coastal Aquifer. The $NaHCO_3$ facies occurs between the fresh and saltwater intrusion zones in the southeastern and inland parts of the study area (see Figure 7). According to the assessment of the chloride content, some of the groundwater in this area has been affected by sea water intrusion. The results of the water-quality sampling indicate that maximum chloride concentration is 2,215 mg/L in the seawater intrusion zone.

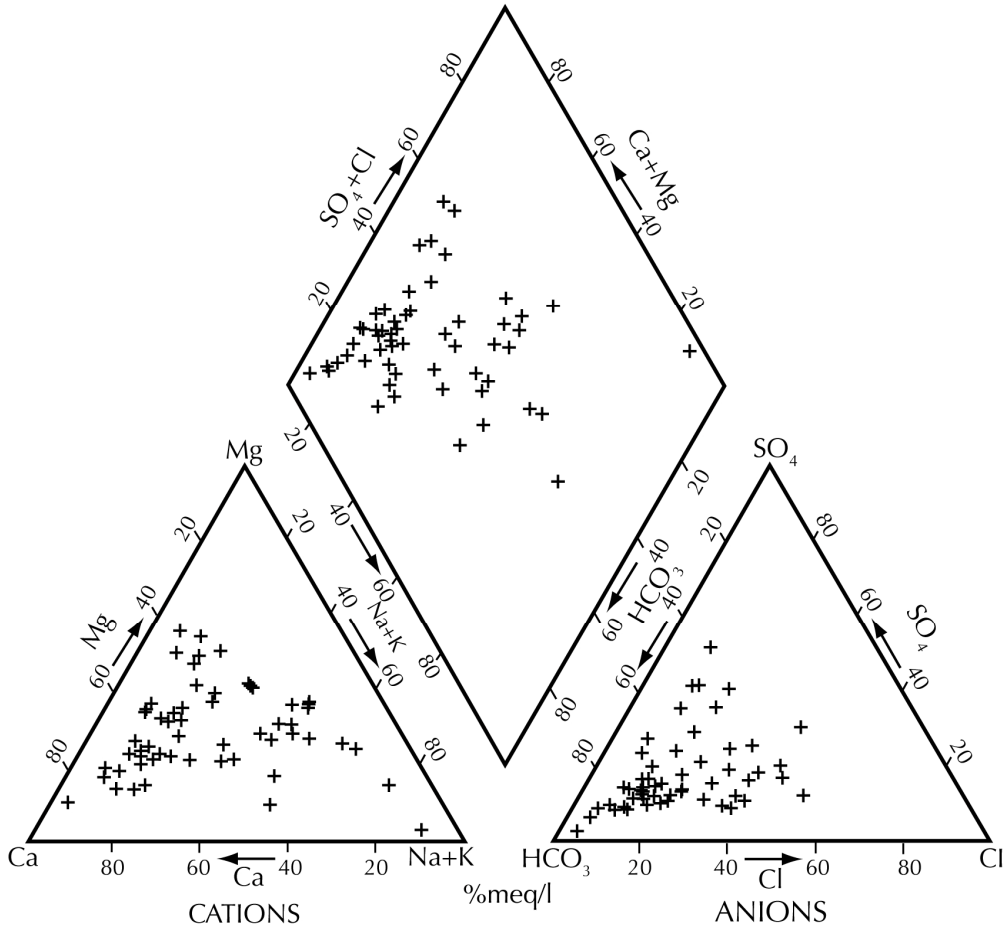

Figure 6. Piper Diagram of the 2002 Period at Mersin

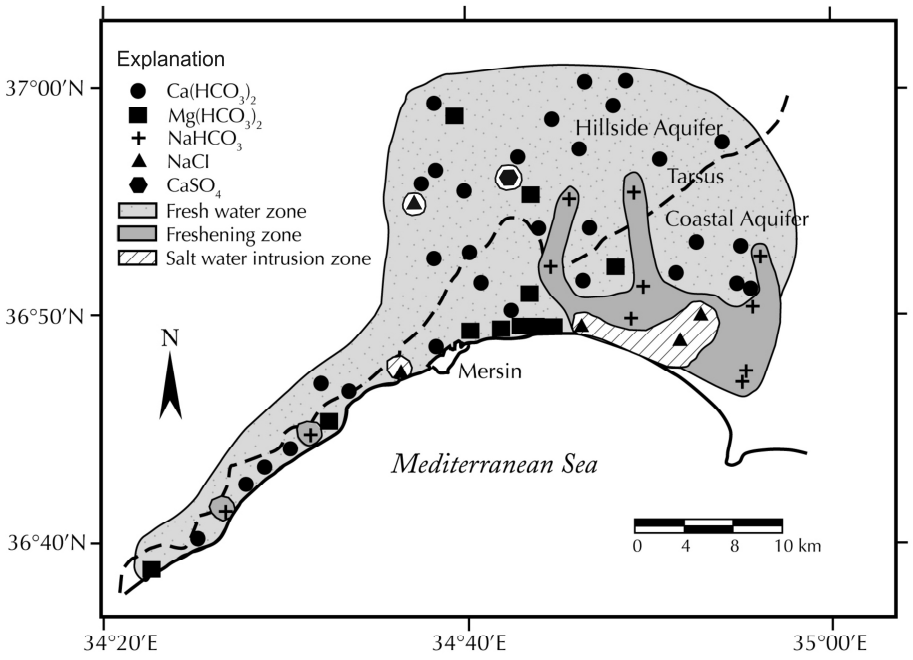

Figure 7. Hydrochemical Facies in the Mersin Aquifers

Acknowledgments

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References

Appelo, C. A. J., and Postma, D. (2005). Geochemistry, Groundwater and Pollution. A. A. Balkema Publishers, 2nd Edition, 649 pp.

Hatipoglu, Z. (2004). Hydrogeochemistry of Mersin-Tarsus Coastal Aquifer, Hacettepe University, Pure and Applied Sciences, Ph.D. Thesis, Ankara, Turkey, 142 pp.

Motz, L. H., Yurtal, R., and Gordu, F. (2005). Final Project Report: Optimization of Groundwater Use Subject to Saltwater Intrusion Along the Mediterranean Coast of Turkey. National Science Foundation, Washington, D.C., U.S.A., and Scientific and Technical Research Council of Turkey (TUBITAK), Ankara, Turkey, 57 pp.