

Study of Saltwater Intrusion into the Coastal Aquifer of Tavabe-e Arsanjan, Iran

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ABSTRACT

Tavabe-e Arsanjan is an agricultural plain located in southern Iran, northwest of Tashk Salt Lake, where the only source for irrigation water is groundwater. Tashk Lake is one of the most salty lakes in Iran with Electrical Conductivities (EC) of up to 61420 $\mu\text{mhos/cm}$. Increasing demand for freshwater and overexploitation of the aquifer has caused a drawdown in groundwater levels followed by a seawater intrusion into the coastal aquifer. A total of 22 observation and sampling wells existed in the area with periodic measurements which were used to study the situation of saltwater intrusion into Tavabe-e Arsanjan aquifer over time. Results show that saltwater intrusion into the aquifer may occur from two main directions; south and southeast of the region originating from Tashk salt lake, and from the northern adjacent aquifer.

INTRODUCTION

Seawater intrusion is a natural process that occurs in most coastal aquifers, but when it causes groundwater salinization, it becomes a concern. There exists no comprehensive review of the extent of saltwater intrusion cases around the world. Well documented cases, however, include for example the Hawaiian, Californian, Floridian, Atlantic and Gulf coastal plains in the United States (Konikow and Reilly 1999). The purpose of this paper is to study the past and recent conditions of salinization in Tavabe-e Arsanjan coastal aquifer in Iran.

SITE DESCRIPTION

Tavabe-e Arsanjan is situated near the Tashk Salt Lake in northeast of Fars province, southern Iran (Fig. 1). The study area is located between 29° 39' and 29° 48' north latitude and 53° 08' and 53° 24' east longitude. Despite the mountains surrounding the region, it has an almost flat topography with an approximate surface area of 248 km^2 . The superficial study area elevation, ranges from 1562 m in the southern corner of the region along the shore of the Tashk Lake to 2270 m in the northern corner on the Siyah Mountain; the average elevation being $\sim 1580 m$. This region is one of the oldest agricultural areas in the world, where farmers extensively use groundwater for irrigation (Nadji 1997). With due attention to the quality of water resources and fertility potential of soil, the major crops in Tavabe-e Arsanjan are wheat, barley, alfalfa and corn. Except the salty land near Tashk Lake, these crops are grown in the whole of the plain.

Climate and surface hydrology

There is not any rain gauge or climatologic station in the study area. The closest rain gauge station in the region is located in Arsanjan, ~ 30 km outside Tavabe-e Arsanjan to the north. According to ~ 15 years of measured data at this station, the average annual rainfall and temperature are about 333.6 mm and 17°C, respectively. Monthly rainfalls fluctuations show that precipitation is increased in the area during winter months and decreased sharply in spring months. Total annual rainfall demonstrates a sharp increase in years 2004 and 2005. Considering these values, Tavabe-e Arsanjan is identified as a region with typical semi-arid climate. The plain is adjacent to a lake, has a small aerial extent with an almost flat topography, relatively

high infiltration rate, and not much precipitation to start with. Therefore, there are no rivers in Tavabe-e Arsanjan and the only source of freshwater supply is groundwater. The highly saline lake (Tashk Salt Lake) with EC of up to 61420 $\mu\text{mhos/cm}$ and chloride concentration of up to 44756 mg/l situated in the southeast of the study area makes the groundwater susceptible to salinization.

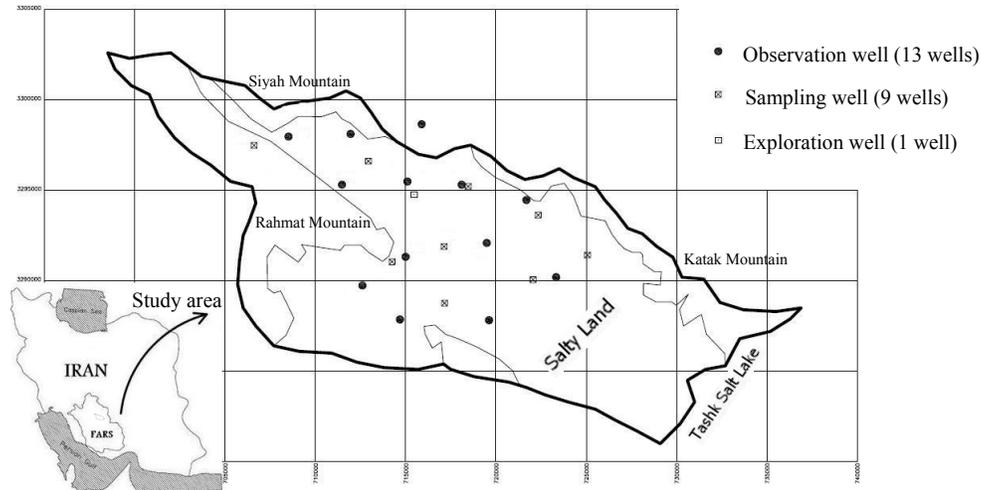


Figure 1: Location of the study area and the wells inside the plain

Geology

Tavabe-e Arsanjan consists of an unconfined aquifer which is filled with Quaternary sediments in its main plain. Thickness of the sediments varies from 30 to 50 m in the northwest, and gradually increases toward the southeast. A maximum thickness of ~400 m can be found near the lake. The alluvial deposits consist of rubble stone, gravel, sand (near the margins of the mountains) with low amount of clay and silt added close to the lake. Mountains formation in the northwest is composed of dense limestone of the middle-upper Cretaceous formation. However, the extent that the limestone is in hydraulic contact with alluvial deposits is not well known (Jooyab Consulting Engineers, 1976).

Hydrogeology

The main source of groundwater recharge in Tavabe-e Arsanjan aquifer is the natural infiltration of precipitation on the basin. 15 existing Qanats in the study area have all dried up over the past 10~15 years, due to the dropping water table (Rasoulzadeh 2007). Fars Regional Water Authority has installed 13 observation wells in the study area, where monthly water table elevation measurements are obtained (Fig. 1). In addition, a single exploration well was drilled to a depth of 115 m by Fars Regional Water Authority in 1974 to perform pump tests and determine hydraulic properties of the aquifer. According to results of the pump test, the average hydraulic conductivity, storativity, and transmissivity of the aquifer are 3.28 m/d, 3.42%, and 446.6 m^2/d , respectively (Acting Organization for Groundwater Management, 1999). In general, water table elevation and slope followed those of topography, with the regional groundwater flow from northwest of the plain to south and southeast. Average water table drawdown in Tavabe-e Arsanjan aquifer during the 13-year period of 1994 to 2007 was 8.6 m; ~0.66 m per year.

Hydrochemistry

EC measurements were conducted twice a year on sampling wells in the region (data not shown for brevity). Well depths are less than 80 m and EC measurements were performed at the upper levels of the wells. Recent EC data indicate that freshwater still exists in the northwestern parts of the aquifer while south and southeast of the area are intruded by saltwater. It basically reflects the fact that in the northwestern highlands, natural fresh groundwater has received no contamination from Tashk Lake. According to the Piper diagram analysis, groundwater of the study area, with the exception of northwest part, is Chloride/Sodium type (Rasoulzadeh, 2007).

RESULTS AND DISCUSSIONS

Water table elevation contours in the study area were drawn based on the monthly measurements in the observation wells. Figure 2 shows such contours for two different dates; Oct. 1994, and Aug. 2007. Regional groundwater flow from northwest to southeast is obvious at both dates. However, an overall drop in water table elevation (up to 12 m) at the later date, and a local cone of depression at the central parts of the aquifer (with its low elevation limb stretching towards the salty lake) is worrisome. The cone of depression would locally draw groundwater from southeast of the region (near Tashk lake) inward; a situation which could lead to salt water intrusion. It is postulated that the installment of (too) many discharge wells, with high rates of discharge, at the central parts of the aquifer has resulted in this worrisome condition.

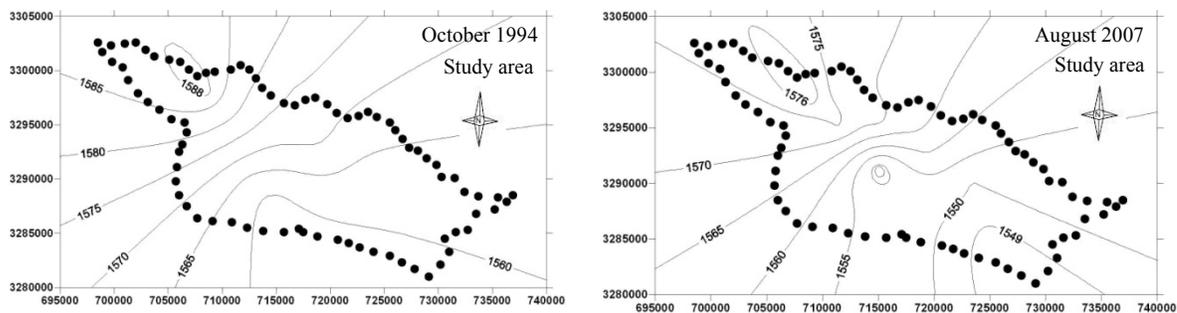


Figure 2. Water table elevation contours in the study area for two different dates (Axes are the U.T.M.: X- and Y-coordinates)

According to farmers in Tavabe-e Arsanjan, groundwater had little significance during 70's. However, in late 80's pumping rates increased drastically following a boost in the number of deep and shallow wells, and this was the start of groundwater quality deterioration in the area. In fact, during early 90's the water table had declined considerably and intrusion of saltwater from Tashk Lake had started. Moreover, the adjacent aquifers were (and still are) contributing some salty groundwater into Tavabe-e Arsanjan aquifer. Those aquifers are in east and northeast vicinity of the study area and are in direct hydraulic contact with Tashk Lake. The extent of saltwater intrusion into Tavabe-e Arsanjan aquifer is shown as contour maps of groundwater EC in Figure 3. Boundary of the study area is marked by white dots on the figure. As shown, during the 1994 there has been a seawater intrusion (fingering) into the aquifer mainly from the northern vicinity. This intrusion shifted to the east in the following years leading to 2000, leaving behind isolated pockets of less salty water in the central parts of the aquifer with ECs lower than 5000 $\mu\text{mhos/cm}$. Contour maps for 2006 reflects saltwater intrusion solely from Tashk Lake's saltwater on the east of the aquifer whilst pockets of EC concentrations in the center are smoothed out. It was concluded that saltwater intrusion in the aquifer may occur from two main directions; south and southeast of the region originating from Tashk salt lake, and from the northern adjacent aquifer.

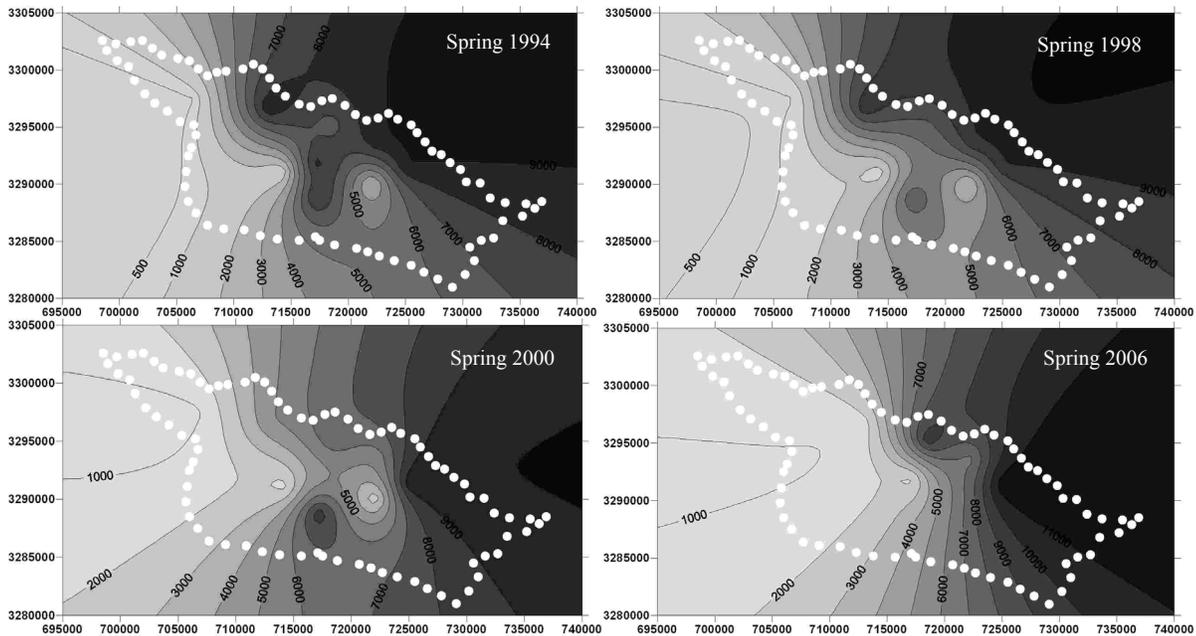


Figure 3. Contour map of EC concentration in groundwater of the study area ($\mu\text{mhos/cm}$) at different dates (Axes are the U.T.M.: X- and Y-coordinates)

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