

Example of Qanats for the Sustainability of Groundwater Usage, Antalya-Turkey

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Abstract. The protection of the existing resources has become much more important than getting fresh water. The traditional methods, like well and pump, can reduce the groundwater level and dry up the reservoirs. On the other hand, there are some environmentally friendly methods like “qanat”. Qanat is a water management system which has been used to supply water in semi-arid and arid regions for a long time; for example, in Iran, Iraq, Morocco, Oman etc. The system consists of many vertical well connected by gently sloping tunnel with tapping into the groundwater table. The main idea is to reduce the evaporation and leakage, keep the natural balance of the groundwater without pumping. The main idea in this study is to find suitable places for qanats in terms of geology and hydrology and to create a model for new water projects in Antalya. A “pilot area” near to Elmalı, which is one of the districts of Antalya, is selected. The geological units in the area are permeable - highly permeable micritic limestone and impermeable - poor permeable claystone – siltstone. The surface waters in the area are generally seasonal. The physical and chemical properties of surface waters were determined. The water in the area was classified “as very good quality water for drinking” and “very good for irrigations”. Besides that, the study showed that “the geological model is very appropriate for “qanat” and to get water by gravitation without decreasing the groundwater table and damaging natural balance”.

1. Introduction

Water, the basis of life, is one of the important vital resources for sustainable development. Unfortunately, while the demand for fresh water is increasing, the amount of freshwater is decreasing because of some reasons such as population growth, industrialization, global warming etc. Besides, some conventional practices, like well and pump, without careful consideration reduce the groundwater level and dry up the reservoirs. There is a clear evidence that groundwater supplies are diminishing, with an estimated 20% of the world’s aquifers being over-exploited, some massively so. Globally, the rate of groundwater abstraction is increasing by 1% to 2% per year [1]. So, the water extraction method becomes much more important to protect the groundwater. Some authors [2] proposed a solution in order to curb the freshwater resource shortage; preventing some storm water from becoming runoff, keeping water clean, storing water underground and using water more intelligently. Besides that, qanat is also one of the important solutions to protect the balance of groundwater especially in arid and semi-arid regions. Qanat is common in arid and semi-arid climate like Iran, Algeria, Egypt, Syria [3,4]. This system makes the groundwater "renewable resources" with minimum evaporation and seepage, without pumping and with protected natural balance. Although



this system has been used in the world, the usage of horizontal wells is unfortunately not very common in our country. The applicability of this environmentally friendly system in the western Mediterranean region is the main objective of this study. The selected pilot area “to create a model” for this study is located in the northeast of Elmalı district of Antalya in Turkey (Figure 1).



Figure 1. Location of the study area

2. Geology

Beydağları autochthonous unit is exposed with Yeşilbarak and Likya nappes in the region. Upper Cretaceous aged Beydağları formation (neritic limestone), Upper Lutetian – Priabonian aged Küçükköy formation (calcarene, sandstone, claystone, etc.), Upper Aquitanian - Lower Burdigalian aged Karabayır formation (limestone) and Burdigalian aged Karakuştepe formation (sandstone, claystone) represent the Beydağları autochthonous unit. Yeşilbarak nappe (=intermediate zone) which has continuity in the lateral direction is located between Beydağları autochthonous and Likya nappes. This nappe is formed by Upper Lutetian - Lower Burdigalian aged Elmalı formation (sandstone, shale) and Upper Lutetian – Priabonian aged Yavuz formation (limestone with sandstone levels, claystone and siltstone). Lycian nappes, composed by structural units in different environmental conditions, are represented by Gülbahar nappe which contains Jurassic – Cretaceous aged Orhaniye formation (radiolarites, cherty micrite, limestone). Besides, Dire olistostrome has been located in the study area. Quaternary aged sediments in various continental facies constitute the neotokton cover rock units and are represented by Quaternary aged talus, alluvial fans (photo 1; figure 2), [5].



Photo 1. A view from the study area

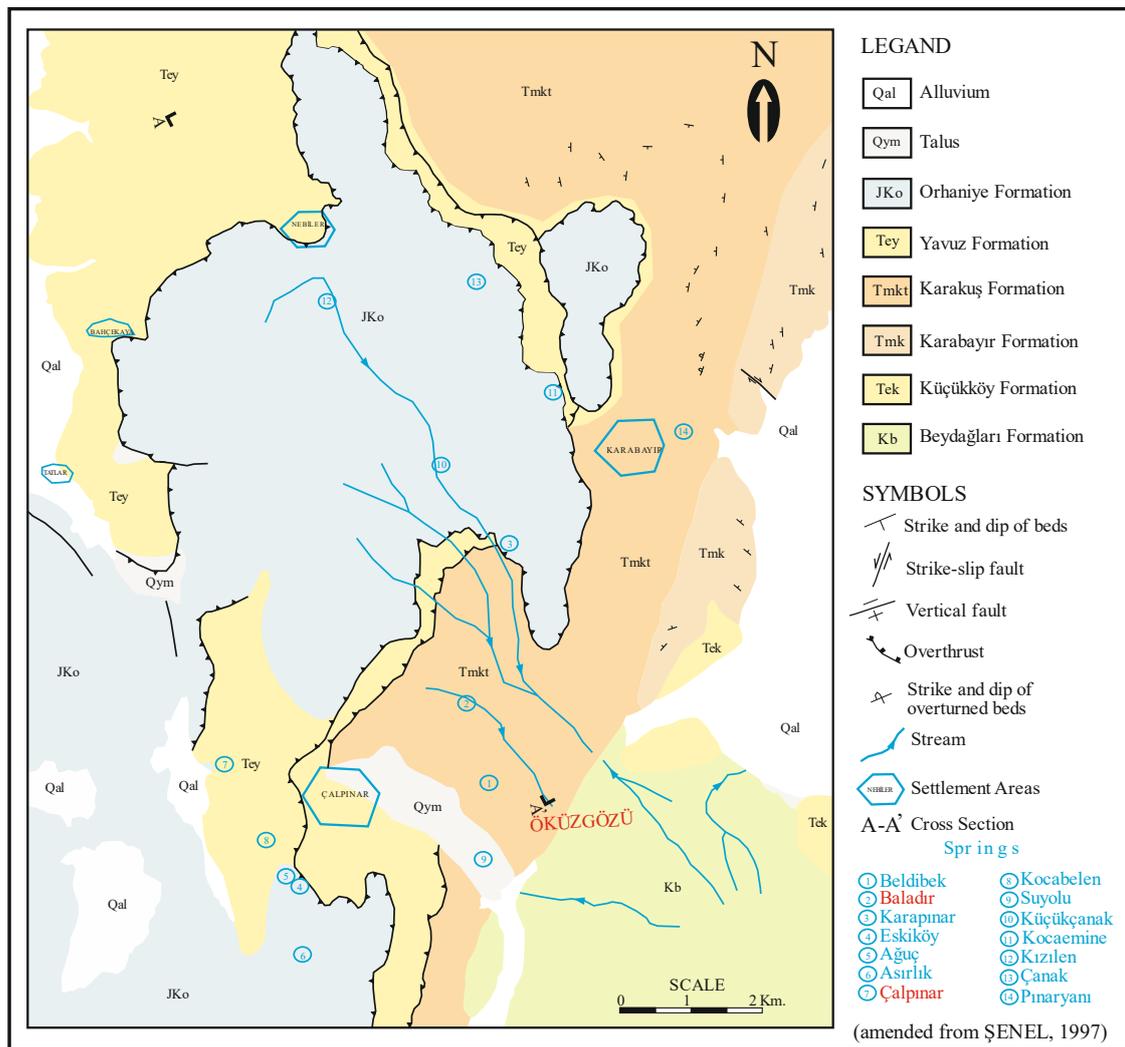


Figure 2. The geological map of the study area

3. Hydrogeology

Even though the study area is a plain, it is surrounded by hills. The highest hill is 2296 meters in elevation; the lowest one is 1100 meters. The climate in the region is continental; winters are cold and generally snowy, summers are hot and dry. There are many creeks and sources in the study area and most of them are seasonal. In situ and also laboratory measurements were made to determine the physical and chemical properties of natural sources. Four sources of them are taken into account (photo 2). The chemical analysis results are given in Table 1. The SAR and % NA results are shown in Table 2. Table 3 shows the classification of water according to French Hardness. The geochemical analyses have been made. Potability diagram of the water according to Schoeller is given in Figure 3. Figure 4 and Figure 5 show the classification of water according to Wilcox and US salinity.

Because of the karstification of Beydağları formation which covers a large area in the region, most precipitation flows into groundwater. The hydraulic conductivity (K, m/s) of the formation is located between 8×10^{-4} and 6×10^{-6} (high permeable-permeable). Precipitation is generally in snow form. Significant portion of the groundwater in the basin is provided by this limestone. Conglomerate levels, which have narrow outcrop, have a hydraulic conductivity between 5×10^{-5} – 10^{-6} (moderate permeable). The hydraulic permeability of sandstone spread over a large area between the 10^{-5} and 10^{-7} (moderate permeability) varies.



Photo 2. Some views from the springs

The hydraulic permeability of siltstone changes between 3×10^{-7} and 2×10^{-8} (less permeable). The outcrop of claystone – mudstone has a wide area in the study region with 9×10^{-7} and 2×10^{-10} hydraulic permeability (less permeable – impervious). The hydraulic permeability of talus decreases from above to down between 10^{-3} and 10^{-6} . The main reason for the high permeability of surface is to be washed down of loose fine-grained material under the action of gravity. The segments with appropriate thickness have aquifer properties. While the alluvial deposits in the creeks are permeable – moderate permeable, the main branches are high permeable.

Table 1. The chemical analysis results of four different sources water (meg/l).

NO	SOURCE NAME	EC (25°C) $\mu\text{mhos/cm}$	CATIONS (Meg/l)				ANIONS (Meg/l)				TOT. IONS (Meg/l)	FRENCH HARDNESS
			Na ⁺	K ⁺	Ca ⁺² + Mg ⁺²	Total	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻²	Total		
1	BALADIR	435	0.26	0.01	3.98	4.25	3.38	0.3	0.57	4.25	8.5	19.9
2	ÇALPINAR	370	0.18	0.01	3.39	3.58	2.89	0.3	0.39	3.58	7.16	16.95
3	ÇOBANİSA	486	0.42	0.01	4.27	4.7	3.96	0.3	0.44	4.7	9.4	21.35
4	BARAZ	450	0.48	0.01	3.88	4.37	3.63	0.3	0.44	4.37	8.74	19.4

Table 2. SAR and % Na values of water.

NO	SOURCE NAME	SAR	% Na
1	BALADIR	0.184	6.117
2	ÇALPINAR	0.138	5.027
3	ÇOBANİSA	0.287	8.936
4	BARAZ	0.345	10.983

Table 3. Classification of water according to French Hardness.

Source No	Source name	French Hardness					
		0-7.2	7.2-14.5	14.5-21.5	21.5-32.5	32.5-54.0	>54
1	BALADIR			*			
2	ÇALPINAR			*			
3	ÇOBANİSA			*			
4	BARAZ			*			
	Classification	Very soft	Soft	Moderate Hard	Quite Hard	Hard	Very Hard

4. Results and discussions

There are seasonal springs but there is no significant surface water in and around the study area. However, the groundwater is used for irrigation. Supplying water in the region will be a big problem in the future according to State Hydraulic Works' data. Additionally, rashly pumping water will enlarge the problem. So, the protecting groundwater and the usage of existing resources became much more important.

The "horizontal well system" or "QANAT" is given in Figure 6. Öküzgözü and around have been approved for QANAT due to the combination of Yavuz formation which is impervious and Orhaniye formation which is permeable aquifer. Karakuştepe formation (Tmkt), Yavuz formation (Te) and Orhaniye formation (JKo) are observed in the region. The elevation of the plain varies between 1260 m and 1400 m. Üstsviri hill has 1400 m -1860 m elevation. The hydraulic conductivity of Tmkt and also Te are below than 10^{-7} (K, m/s); on the other hand, the JKo's hydraulic conductivity is more than 10^{-4} . The contact among three units is thrust. Orhaniye formation consists of permeable limestone with high elevation and snow precipitation; so, it feeds groundwater. The groundwater flows to the southeast. Thus; with a QANAT system, which will be located at the southeast of Üstsviri hill with 1500 m elevation, the groundwater can be taken by gravitation without damaging nature balance. As shown in the figure, the horizontal well to southeast cuts all the aquifer. The geometric properties of QANAT (width, length, slope, etc.) which will be determined according to the hydraulic parameters of the aquifer are excluded from the scope of this study.

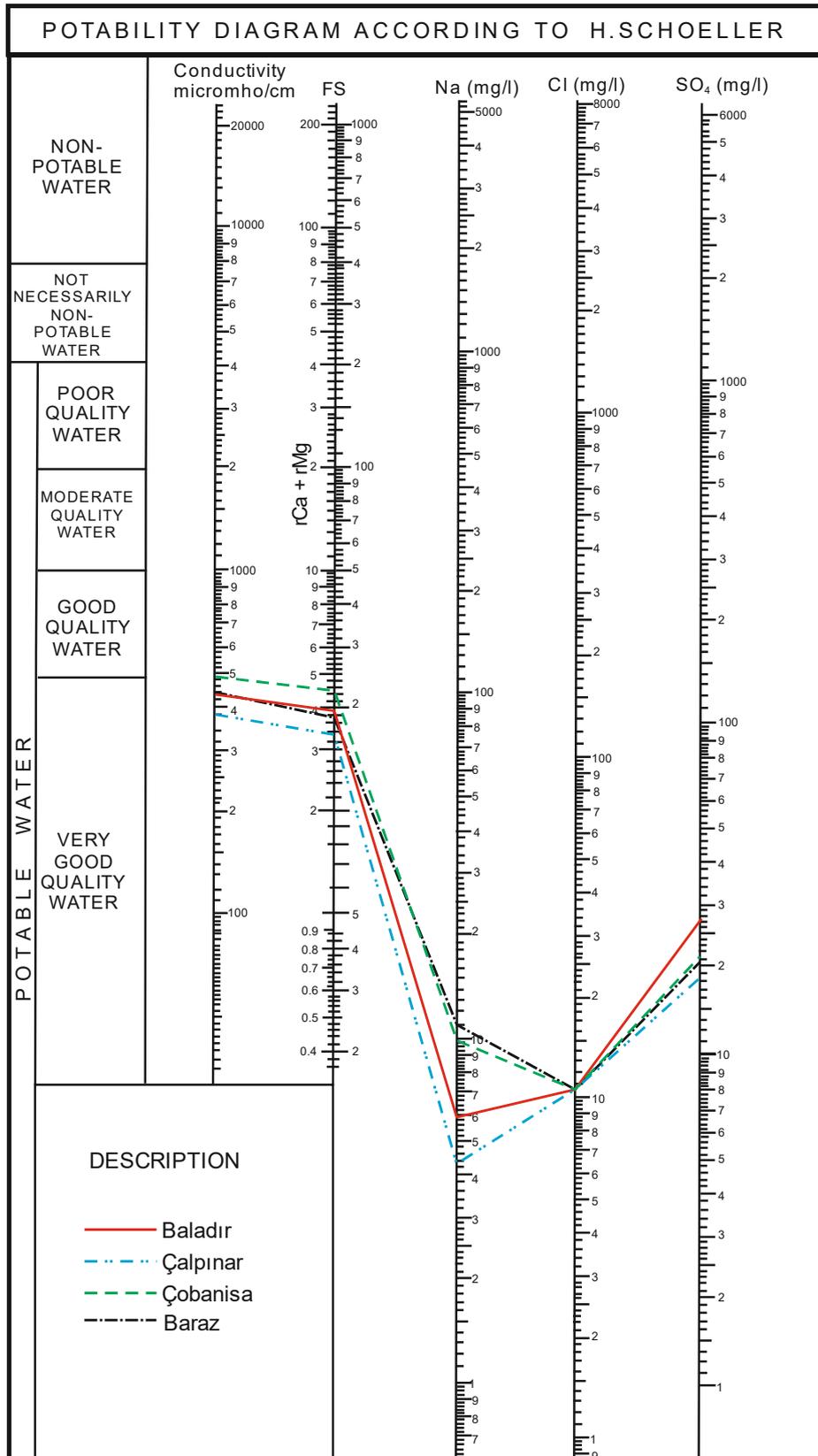


Figure 3. Potability diagram of the water according to Schoeller

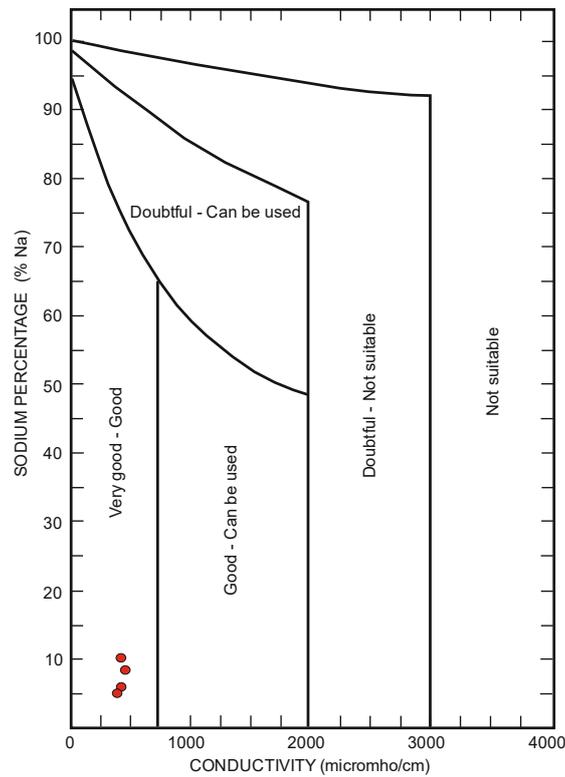


Figure 4. Classification of water according to Wilcox diagram

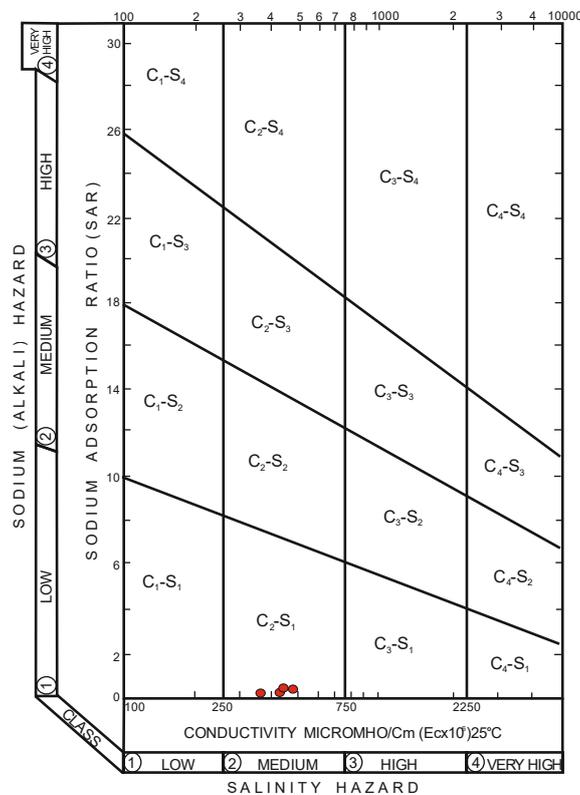


Figure 5. Classification of water according to US salinity diagram

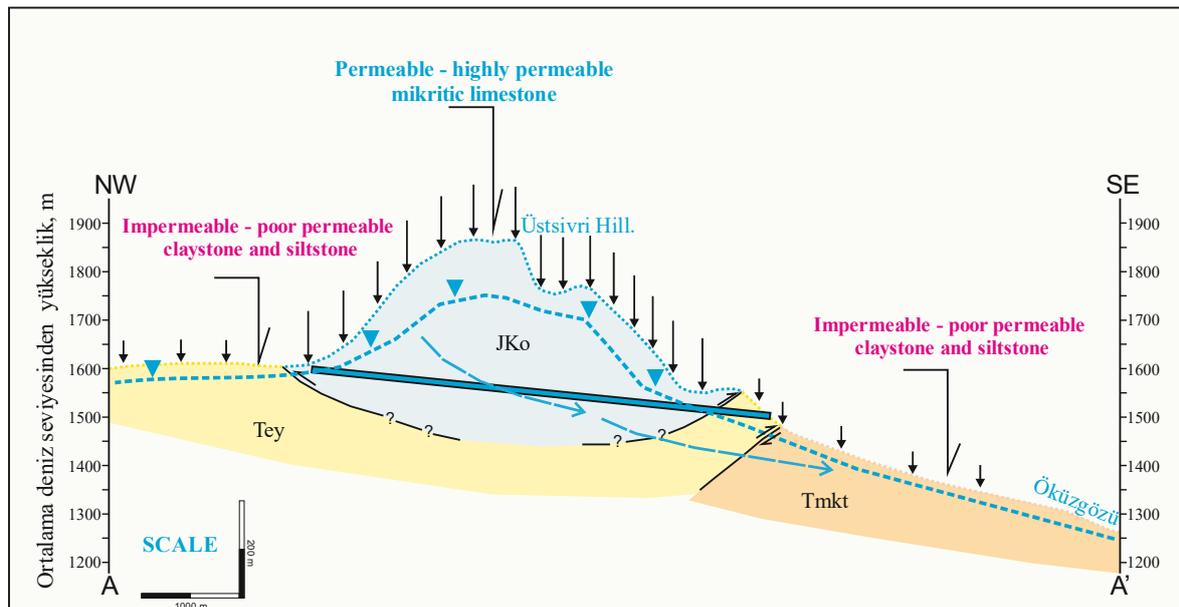


Figure 6. The proposed qanat system in the study area

5. Conclusions

The need for fresh water is increasing day by day in our country like in the rest of the world due to global warming, population growth, migration, industrialization, rising living standards. Besides the increasing demand, one of the reasons for water scarcity is the usage of water unplanned and uncounted. The number and the distance of wells can cause reduction of groundwater and even seawater intrusion in coastal areas. However, the horizontal well system (QANAT) which has been used for 2700 years, makes the groundwater “renewable sources” in arid/semi-arid areas. Because the system minimizes evaporation, gets water by gravitation, reduces energy consumption and protects natural balance. This system will be effective in solving water problems.

The permeable units with high elevation and the impervious units with lower levels have been scanned in this study. Eventually, Öküzgözü and surroundings has been selected due to combination of Orhaniye (high elevation with permeable aquifer) and Yavuz (lower elevation with less permeable-impervious) formations. These properties of lithological units and the presence of reverse faults between them, groundwater level is easily rising in Orhaniye formation and water can be stored underground. Thus, it will be possible to get water by gravitation without decreasing the groundwater table and damaging natural balance with QANAT at the southeast of Üstivri hell. The direction of flow trends to southeast is also effective on site selection. The length of the horizontal well which is inclined to southeast should be along the aquifer.

Acknowledgment

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