



IWA-PPFW 2017

2nd IWA Regional Symposium on Water,
Wastewater and Environment

The Past, Present and Future of the World's Water Resources
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PROCEEDING BOOK

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PREFACE

The 2nd Regional IWA Symposium on water, wastewater and environment is hosted by the Izmir Institute of Technology in Çesme-Izmir, Turkey between the dates of March 22 and 24, 2017. Following the previous IWA conferences, the theme of this conference was ‘The past, present and future of the world’s water resources’ which established the trend of thinking of the participants and determined the composition of the papers those were presented. Inspired by the IWA’s vision that is ‘A world in which water is wisely managed to satisfy the needs of human activities and ecosystems in an equitable and sustainable way’ the community of professionals concerned with water, presented their experiences for sustainable urban and basin-related water solutions.

The purpose of the symposium was to highlight water as a source of life and to stress the need for water cooperation between all actors in society to protect its value and exchange ideas between academia and industry on various forms of water cooperation that are fundamental to water use and water management. Also to identify good practices for water cooperation and demonstrate its merits for poverty eradication, economic development, environmental sustainability and peace.

The conference technical programme was organized in the following general areas: Water Treatment; Ancient Water Systems; Water Resources; Hydrology and Hydrogeology; Modeling and Simulation; Water Quality; Waste Management; Ecotoxicology and Health Risks and Water Reuse. We hope that the contents of the related papers will be beneficial source of information on water, wastewater and environment related engineering applications.

211 abstracts were presented in 30 sessions during the three days of the conference. We wish to acknowledge and express our sincere gratitude to the Organizing Committee for their valuable efforts and to the Scientific Committee for their precious time spent in reviewing of the submitted papers.

On behalf of the Organizing Committee

Prof.Dr.Alper BABA

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Ancient Water Supply Systems and Waterways; Kehriz System in Şanlıurfa

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ABSTRACT: In this study; ancient water supply systems and their transmission structures, called kehriz, in Şanlıurfa Province which were built in ancient times are investigated and mapped in details. As one of the oldest cities in the world, Şanlıurfa is hosting many civilizations throughout the history, since 11500 BC. The existing materials related on archaeological heritage shows that the Şanlıurfa city has very important water supply and transmission experiences. Kehrizes are ancient and interesting water transmission structures that convey water from far away to meet the needs of people by hand-made galleries. Three main waterways in Şanlıurfa Province; Old Kehriz, New Kehriz and Germüş Water, as important and interesting water structures, are studied and documented in Şanlıurfa Province. Throughout the history of the city, different communities using the city destroyed most of the cultural structures of earlier civilizations. However, all communities have protected and developed water supply systems. Therefore, water structures remain up to now and some of these systems are still in use.

1. INTRODUCTION

Kehriz (or karez or qanat) is the name of an underground water transmission system that allow the water to flow in horizontal galleries in their own inclination (1% to 0,06%). These are a form of subsurface galleries that collect ground-water and direct it through a sloping underground canals to the surface channels which provide water for irrigation areas.

Water flows through the walls of a main well and then is carried by natural gravity flow through the qanat channel. While a single tunnel fails to feed an adequate flow, other infiltration channels which yield into the main tunnel may be added. Qanats are the most ecological and balanced water supply methods available for arid places (Figure 1). Qanats are found throughout the Islamic world and Far East and some West countries. (Lightfoot, 1996; Ali Hamidian et al., 2015).

Construction processes of qanat structures are also similar, and wells which have same functions can be found, having 50–100 m intervals (English, 1998). The working procedures of these structures have some similarities today, although the differences in exist technology, (Carrion and Fornes, 2016). Beside these, the qanat systems may not be applicable for solving the today's water scarcity problem in arid and semiarid regions of the world.

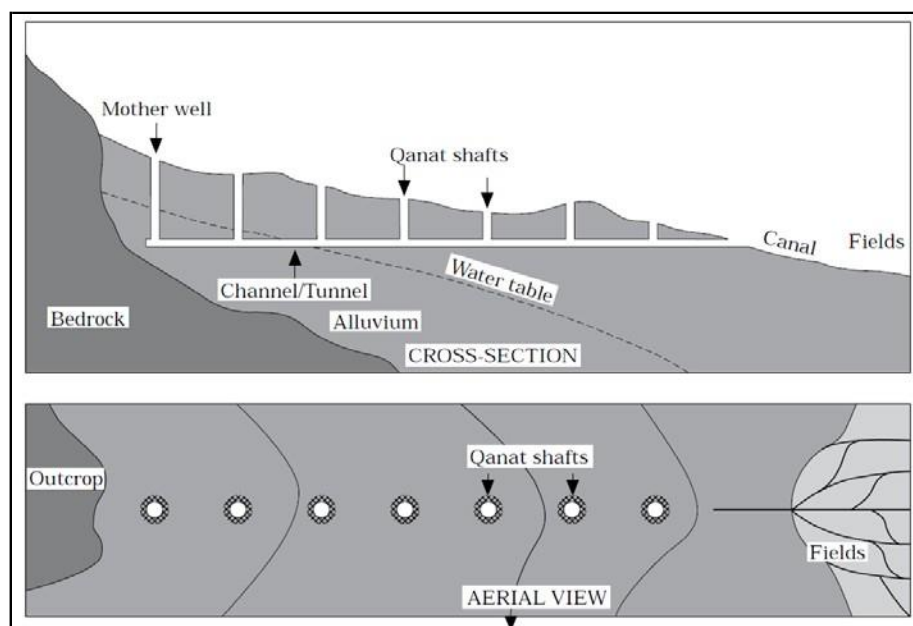


Figure 1. Plan and profil view of typical qanat (Lightfoot, 1996)

Due to the widespread distribution of qanat technology and known by different local names, it is difficult to say the origin of the name of that ancient hydraulic structures. But, according to the common literature, qanat is the oldest name of that structure. (Fattahi, 2015). The kehriz system is named with different names in different regions (Lightfoot, 2000; Mays, 2010; Fattahi, 2015; Hamidian et al, 2015; Ozden, 2011), (Table 1).

Table 1. Naming of (kehriz) karezes in different regions.

Kahriz/karez	<i>Azerbaijan, Turkmenistan, Iran, Iraq, Afghanistan, Pakistan</i>	Falaj	<i>United Arab Emirates, Oman</i>
Kanerjing	<i>China</i>	Khettara	<i>Morocco</i>
Qanat	<i>Iran</i>	Galleria	<i>Spain</i>
Qanat Romani	<i>Jordan and Syria</i>	Kahn	<i>Baloch</i>
Ain	<i>Saudi Arabia</i>	Foggara	<i>Algeria</i>
Fughara, Khettara, Iffeli	<i>North Africa</i>	Galerias	<i>Canary Islands</i>
Mambo	<i>Japan</i>	Inguttati	<i>Sicily</i>
Kehriz, Galeri, Kina, Lağam, Keriz			<i>Anatolia, Turkey</i>
Khad, Ghundat, Kanat, Fokkara, Kona, Kunut			<i>Others</i>

Some details of kehriz construction steps are shown in Figure 2.

The qanats were in the focus of the formation of civilization in several parts of the world. The kariz structures have been used for hundreds of years in Southern Afghanistan regions such as Kandahar, Uruzgan, Nimruz and Helmand. In Azerbaijan, there are wide areas under irrigation with Karezes such as Zencan, Gence, Karabakh, Nakhichevan and Baku. In Eastern Turkistan's Turfan region, Uighur Turks made kariz water channels 2500 years ago and some of these lines can still be used today. In the middle of the twentieth century, it is estimated that about 50,000 karezes are in use in Iran. There are five medieval settlements in Kazakhstan using karezes which are Sauran, Turkestan, Chernak, Babaikorgan and Karachik. A large number of cities were found in Syria having kehriz systems, but very common ground water pump arrangements have lowered the water level in the groundwater

level and the kehriz scheme. So the kehrizs dried up and were abandoned nationwide. The palm gardens in the wake of Al-Ayn in the United Arab Emirates are still irrigated with traditional palate (qanat) orders. In Oman, close to 3000 kehriz systems are used (Ozden, 2004, 2008, 2010; English, 1998).



Figure 2. Some details of kehriz construction steps from BBC documentary (BBC, 2011)

Due to the widespread use of pumps, many of the qanats have been closed today. But in some regions like e.g. Afghanistan, China, Pakistan, Azerbaijan, Iran, Oman, etc. qanats are still under usage and supply a large amount of water to the agricultural areas. Some regions such as Iran, Afghanistan, Pakistan, Oman and China still enjoy working qanats (Hamidian et al., 2015).

In Turkey, The roots of Anatolian water culture can be shown in some cities of Turkey which are the cradle of civilization since Paleolithic Age. Cultural marks of water structures that belong to Sumerian, Hittite, Phrgian, Persian, Akkadian, Urartian, Arabic, Roman, Byzantine, Seljuk and Ottoman Periods have been identified as engineering wonders of a civilized society. Anatolian karez (qanats) as a part of ancient structures of water civilization, are common productions of the united public will. These structures as the cultural heritage of mankind are independent of its geographical origin.

According to Özden (2011), at 66 locations in Anatolia, many historical water structures of the karez system can be found. Ferhat Water Channel, which is located in Amasya (24 km long), is a typical karez system from the Anatolian Karez that was built 13 thousand years ago. In Van, only two of the 48 karez, which were built during the Urartian period thousands of years ago, are left today. In some provinces eg. Amasya, Tokat, Van, Bitlis, Batman, Hasankefy, Mardin, Diyarbakir, Sanliurfa, Mersin, Niğde, Nevsehir and some others, karez systems still exist.

Especially, Şanlıurfa (Urfa or El-Ruha or Edessa) is accepted as one of the most ancient city in the world. The findings about the city go back to 11500 BC. Most of the historical sources describe Şanlıurfa as a 'water abundant city' although it is located in the hot and arid region of Turkey. As one of the ancient names of Şanlıurfa, Orhay is accepted as a distorted version of 'Kallirrhoe' (beautiful city of watercourses), or in Arabic 'wariha' (abundant in water). (Çeçen and Gökçek, 2005; Segal, 1970; Yenigun et al, 2012; 2013).

There are several publications (Kürkçüoğlu; 1990; 1992; 2011, Segal; 1970; Temizsoy, 2005) focusing on the archaeological features of the water resources and water structures of Şanlıurfa. However, there is not any literature to identify its functionality, updated position and technical details on the map including the hydraulic assessments.

Depending on the the aim of the study, three ancient water source and their transmission systems throughout in the city were investigated and determined. As a result of the study, maps that present pictures of Kehriz systems, many of which are dry, are produced showing the location and status of karez with their additional structures in the city. In the manuscript; structure, function and also distribution of Germüş karez in Şanlıurfa is determined, documented and illustrated using site study data.

2. ANCIENT WATER RESOURCES AND KEHRIZ SYSTEMS IN ŞANLIURFA

2.1. Background

Şanlıurfa is located in the southeast of Turkey, between longitudes 36 40 and 38 02 E and latitudes 37 50 and 40 12 N, where the elevation varies between 500 and 1,000 m. Until very recent times, there were many water sources in the center of city and in the near vicinity, such as; Khalil-al Rahman (Prophet Abraham) and Aynzeliha Lakes, Karakoyun Stream (Daisan Water) and Direkli, Devtesti, Bamyay, Cavaşak, Kehriz, Karaköprü Streams. Beside these; Yukarıkoymat, Gölpınar, Anzelişınar, Germüş, Belih, Tülmen, Cülmen, Tatarhöyük, Yarımtepe, Esemkulu, Kırkpınar and Köprülük streams were the most important water resources of Şanlıurfa (Şahinalp, 2005; Temizsoy, 2005). However, reduction in rain and snow and some other reasons have caused the majority of these sources to dry up (Tonge, 2009). Şanlıurfa's current water resources are given in Figure 3.

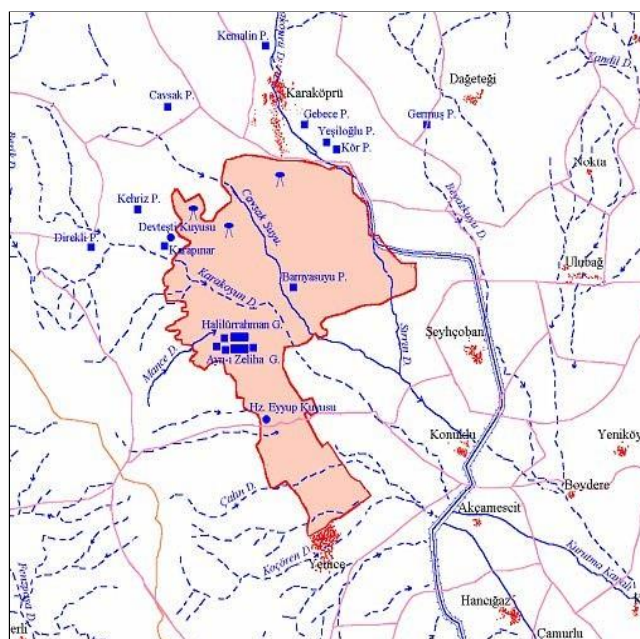


Figure 3. Water resources of Şanlıurfa at present.

According to Kurkcuoglu (1992), the main ancient water resources and their transmission lines are explained below;

a) **New Kehriz**; an ancient water, originated from the source in Aşık Village, located to the north of the city and 15 km from the center, had brought to the city center by human-made underground water channels. This water, conveyed through channels called Kehriz, came to the water channels beneath the balustrades of the Justinian Aqueduct and the Millet Bridge, and from there reached the distribution structure (maxem) on the Water Square. Here, the water is divided into three branches and distributed to some houses, mosques and baths by pöhrenk's (Pöhrenk is a water pipe which 30-35 cm in diameter and 15-20 cm in length, made of potter). Since the end parts of these pipes were designed as a cross-shaped pipe, the pipes were extended until they were connected to each other.

First line reaches to the Yusuf Pasha Mosque and Vezir Bath, second line reaches to the Adile Hanım Fountain in Kubbemescid Street, then to Sakıbiye Tekkesi and the third line reaches to Grand Mosque, Firuz Beg Fountain, then to Ağ (Nimetullah) Mosque.

b) **Old Kehriz**; it was a small water that originated from the Direkli Source on the west side of the city and merged with Halilu'r-Rahman water in the city center according to the expression of local resources.

Both karezes (kehriz systems) had been destroyed and today they are lost in a great extent.

c) **Halilu'r-Rahman (Prophet Abraham) Water**; it was born in the south side of the city center and reaches to the mosques and fountains on the line that takes place on south of the city.

d) **Germuş Water**; that ancient water source at Germuş Village, located in the north-east of the city, has reached the present.

Apart from these sources, there is a kehriz system called "kına", located in Şanlıurfa/Birecik District, Gilbas Village. It is also said that the ancient water channels that similar to the Kehriz system, are exist in Suruc Plain near to Şanlıurfa.

3. DETECTION OF ANCIENT WATER RESOURCES AND THEIR TRANSMISSION ROUTES

In this study, as a part of wide study on “ancient water resources and historical water structures of Şanlıurfa”, at the end of the survey and detailed field investigations, the ancient water resources and their transmission systems in Şanlıurfa are determined as follows:

Firstly the locations of these water resources were determined by GPS receivers. Then, all the routes of the transmission lines, open or close systems, were followed point by point. All shafts (ventilation chimneys), wells, water structures on the route and etc were positioned and documented. All data were processed by using NetCAD and ArcGIS softwares. After generated the map of all routes, the first figure of main ancient waterways appeared in Figure 4.

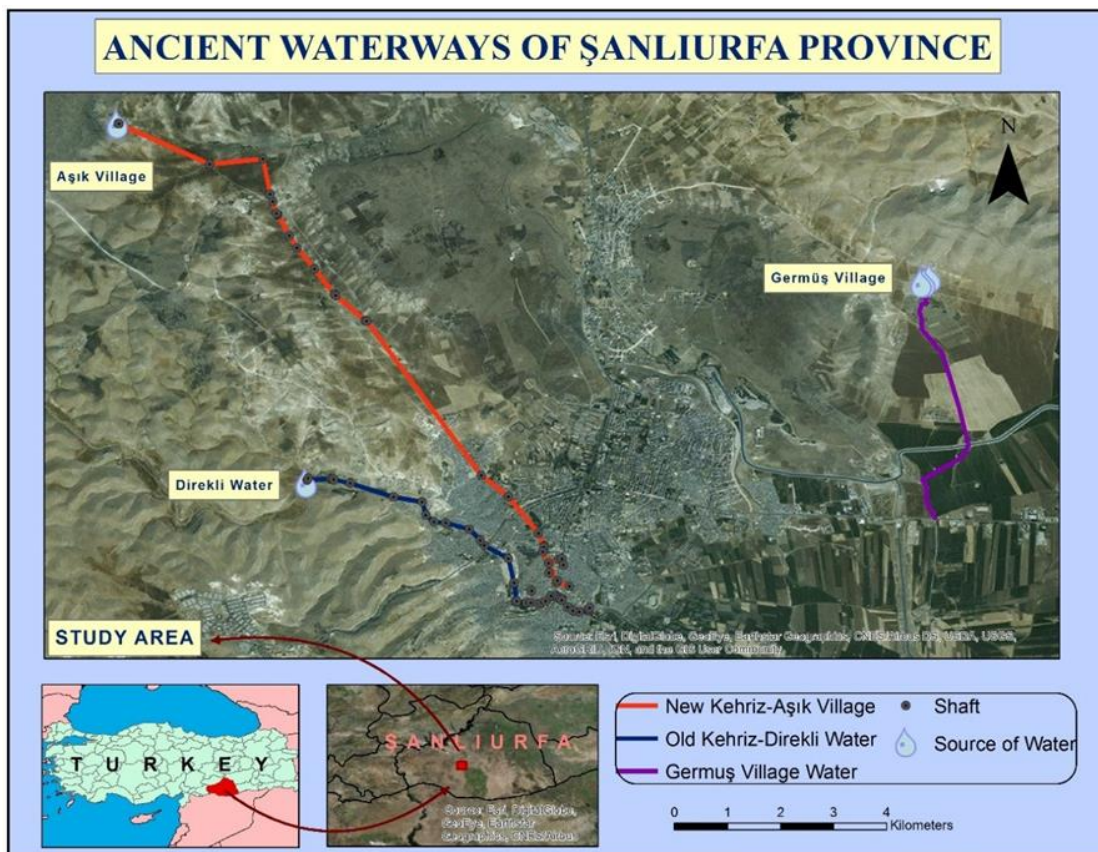


Figure 4. Location of the Study Area - The Ancient Waterways of Şanlıurfa with their origins and routes. 1) New Kehriz, comes from Aşık Village, is the longest ancient waterway of the city. 2) Old Kehriz, comes from Direkli region, were shown together with HalilurRahman Source which is known as Sacred Pool of Prophet Abraham. 3) Germüş Water, comes from Germüş Village, is continuing in an open channel.

Figure 5, shows the Germüş Water and its details. It is shown in Germüş Village which is located at northeast side of the city center and 15 km far away. Germüş Village is an old village that has several big stone houses and historical Germüş Church.

Three kehriz are known to be fed from the water sources in the north and east of Germüş. These tunnels are covered with rubble and were made in an arch shape. A person can walk comfortably for cleaning and maintenance in it. There are ventilation chimneys at regular intervals on the galleries. The system's plan is given in Figure 5-c.



Figure 5. The route of the Germüş Water and its details. a) The middle and big springs were connected and continued in an open channel. b) A kehriz water is using in structures, made of regularly cut stone and were taken down by stairs in houses, (Uceymi Sadun Pasha House), c) The plan of kehriz system of Germüş (from Bildirici, 2009), d) A water usage structure on a kehriz system in the village square. It is also a ventilation structure. e) An another ventilation and water usage structure on dry kehriz spring.

It is known that the kehrizes that feeds the Middle and Big Springs, come from the patches of the mountains on the north side of the village. In the 1990s, these kehrizes that were in working and could be enter and clean. These two kehrizes are connected to each other by inner connections. There are air shafts (ventilation chimneys) along the route. These structures, in most of house of the village, were also serving as wells and the houses were using the water need.

However, most of these wells have filled of due to the lack of maintenance. Most of these wells were made of regularly cut stone and were taken down by stairs and was taken water. That water continues down as an open channel after leaving the village (Bildirici, 2009).

The first gallery that receives water from Little Spring, comes from Diphisar village which is 25-30 km north-east of Germüş. In the past, it was giving water to the irrigation, but today, it is dry due to the lack of maintenance. Figure 6 shows the kehriz galleries of Little and Middel Springs of Germüş Water.



Figure 6. The details of kehriz galleries of Little and Middle Springs of Germüş Water; Views of Circular Galleries and Stone Braid Walls of Tunnels, from Site Study of the Authors.

4. RESULTS AND DISCUSSION

Şanlıurfa as one of oldest cities in the world, has many ancient water structures such as aqueducts, tunnels, galleries, cisterns and etc. from the old civilizations. Center of the city is decorated with water structures such as Turkish baths, aqueducts, water balance facilities, water distribution structures, wells, fountains, and cisterns. Water structures of the city were located and fed on the ancient water transmission system that called “kehriz” in the old city center of Şanlıurfa.

In this study, as a part of wider study that investigation of the water supply, distribution, storage and usage structures in Şanlıurfa; the ancient water resources and their transmission lines are evaluated and documented in their origin, location, position, old and today's photograph with technical details.

According to the results, qanats (or kehrizes - karezes) are the sustainable technology for groundwater management and also complied the social, environmental and economic circumstances of the arid regions.

During the history of the city, although the settled communities have destroyed many of the cultural structures of previous civilizations, they have protected and developed water supply systems. This situation has meant that water structures have lasted to the present and it is interesting to note that some of these systems are still in use. As a cultural heritage karezes are still tell us our past and roots.

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