ANCIENT RAINFALL HARVESTING AND STORAGE SYSTEM IN KISH ISLAND PERSIAN GULF, IRAN

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ABSTRACT

Our intelligent ancestors have tried to convey fresh water from mountain downhill areas into desert lands through a system they themselves had invented: QANAT. One of the interesting qanat systems is located in Kish Island in Persian Gulf. This qanat system has drawn attention since 1992. Surveys show that the system dates back more than 2000 years ago. The system and its associated underground city is one of the worth-seeing places of Kish Island. There are several qanats in the island. Numerous wells have been installed along the qanats paths, mainly used for recharging and dredging purposes. The wells are spaced about 15 meters from each other. Qanat top consists of coral formations with 2 to 15 meter thick. Qanat bed comprised of impervious marl stones. This combination cause the percolated rainwater through the coral layer is stored over the impervious marl layer developing shallow groundwater aquifers. Overall function of the Kish qanat system is rainwater harvesting and collecting, underground storage of water, conveyance and distribution of the stored water. This paper intends to introduce this amazing unique qanat system and its functions and performance.

INTRODUCTION

In the ancient periods, when our ancestors understood the value of water for agriculture, they recognized the importance of water control and storage. Actually, the controlled water we have nowadays in our dams reservoirs and the measures undertaken to exploit and recharge the groundwater resources is the pure fruit of an attempt began on those era. In this regard, the Iranian nation has contributed a lot to this issue. One may recognize the Iranian approach, methodology, level of knowledge and experience towards qanat installation upon observing these historical workman pieces. Investigations show many similarities between modern and ancient hydraulic systems. Scrutinizing these valuable historical heritages would help us to resolve the complicated problems we encounter nowadays in water resources issue.

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Iranian people whose lands are located in an arid and semi-arid climate have prevailed on climatological constraints by incorporating several different techniques originated from their inherent intelligence. Construction of different structures for water control, storage and conveyance such as dams, barrages, water stores (ab-anbar) and Qanats reveals their wise attention for optimum water resources exploitation. Most of these structures and systems are considered among successful architectural structures drawing applause and wonder of those who carefully observe them. In this regard, qanat systems that were usually exercised in arid areas around desert lands to exploit groundwater resources are considered as one of the oldest groundwater conveyance systems. This article intends to introduce one of these remarkable qanat systems located in Kish Island, Persian Gulf, Iran.

HISTORICAL BACKGROUND AND LOCATION

Kish qanat system is one the most ancient hydraulic systems in Iran being still operated in some parts. Based on conducted scientific investigations, this system is one of the historical proofs of comprehensive understanding of its designers and constructors regarding meteorology, hydrology, climatology, geology, structural materials and groundwater hydraulic behaviors.

Kish qanat system is located in Kish Island in Persian Gulf, south of Iran. The system had been installed to optimally store rainwater in underlaying geological layers to supply drinking and agricultural water demands. In far past, the system also supplied water to sailing ships and inhabitants of neighboring islands and cities. There were totally 5 qanat systems located in north, west and south parts of the island. Nowadays, there are traces of only 4 of them. Time of construction of these systems is not known specifically. However, the Dahou qanat system, which is one the main qanats still being operational and located in northeast of the island, dates back to 300-500 years before Christmas with an age about 2300-2500 years. Location of Kish Island and its qanats is shown in figure 1.

Figure 1 - Location of Kish Island and its Qanats

CLIMATOLOGY OF KISH ISLAND

Kish Island is one Persian Gulf Islands located 50 km in south west of Lengeh Port in Hormozgan Province. The island has an elliptical shape with 15 km length in east-west direction and 5 km width in north-south direction. Area of the island is a bit more than 90 km^2 with its highest point at +45 m above sea level. Having a dry climate, the island mean annual rainfall is about 183 mm. Recorded rainfall statistics show irregular and severe variations in rainfall distribution over the island. In this regard, more than half of annual rainfall occurs in just three days in most years. Considering monthly distribution of rainfall reveals that there is about 66 percent of annual rainfall in winter (indicating Mediterranean system domination), 29 percent in autumn, 3 percent in spring and only 2 percent in summer. Amounts of maximum daily rainfall based on Gambel probability distribution are presented in the following table:

Maximum Daily Rainfall Based on Gambel Probability Distribution

Return Period (Year)	2	5	10	20	50	100
Max. Daily Rainfall (mm)	49.97	58.58	109.5	132.2	161.5	179.9

Average annual temperature in the island is about 26.7 ^oC with 6 months having an average temperature above 30 ^oC. Also, the monthly mean temperature is never below 18 ^oC. Reviewing the temperature records of the island shows that the island does not have a four-season climate. In other words, the island only has one hot season (from April to September) and one cool season (from October to March). The notable fact regarding temperature variations in the island is its fluctuation being occurred all above zero ^oC. Relative humidity is more than 70 percent in 11 months while only in November it is between 50 to 70 percents. However, the island suffers sultry only during 6 months with southern parts being more humid than the northern part.

TOPOGRAPHY AND GEOLOGY OF KISH ISLAND

Kish Island is one of the Zagross foot stretched folds with low amplitude. The island, contradictory to other Persian Gulf islands which are originated from Camberian mass grouts, is originated from Zagross orogenic activities. From a geomorphological point of view, the island is a plain and even island with a few scattered features having a maximum elevation at +45 m above sea level. Topography map of the island is shown in figure 2.

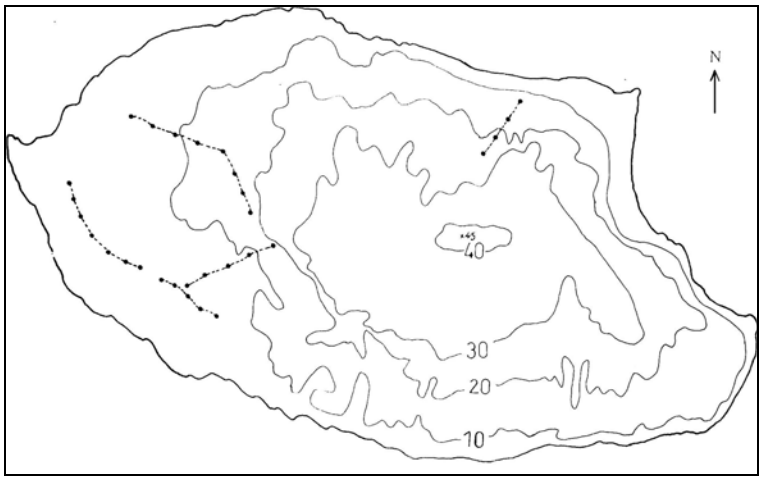

Figure 2 - Topography of Kish Island

Surface of the island is covered with fresh sediments due to repeated advance and recession of water over the island. The majority of island surface area is covered by loose and firm coral limestones (about 91 percent). Some very small areas are covered by clayey soils and wind and coastal sands. Loose coral limestone covers about 72.6 km^2, 80.7 percent, of the island surface. Permeability of these materials is about 10^{-3} cm/s. The high permeability of these materials together with gentle slope of the island are the two dominant factors regarding rainfall absorption.

The Kish Island body is comprised of alternate coral and lime stones with an impermeable marl layer being in between. Permeability of the marl stone is about 10^{-7} cm/s. In fact, these coral and lime stones are good reservoirs to store rainfalls fresh waters. Thickness of upper permeable layer is decreased from the island centre to coastal areas. This results in reduction of potential volume of water storage and groundwaters become shallow. Investigations show that moisture regime of island soils is Aridic border to Ustic. Therefore, soils are dry during more than 9.5 months and they are semi-dried or moist only in the left 2.5 months. Temperature regime of island soils is Hyperthermic indicating a mean annual temperature above 22 ^oC.

PHYSIOGRAPHY, HYDROLOGY AND HYDROGEOLOGY OF KISH ISLAND

The Kish Island surface is comprised of 11 subbasins. Three subbasins covering one third of the island area lack any water courses. Therefore, one can conclude that only the rainfall over remaining 57.7 km^2 of the island is runoff producing. According to conducted investigations, average runoff coefficient of the island is about 17 percent. Accordingly, considering the infiltration potential of the upper surface layer of the island, more than 80 percent of precipitated rainfall in infiltrated into the surface layers of the island. In other words, there is a potential of 16 Mm^3 of infiltration into the island upper layers. There are also 6 groundwater basins in the island. Watersheds and groundwater basins of the island are shown in figure 3.

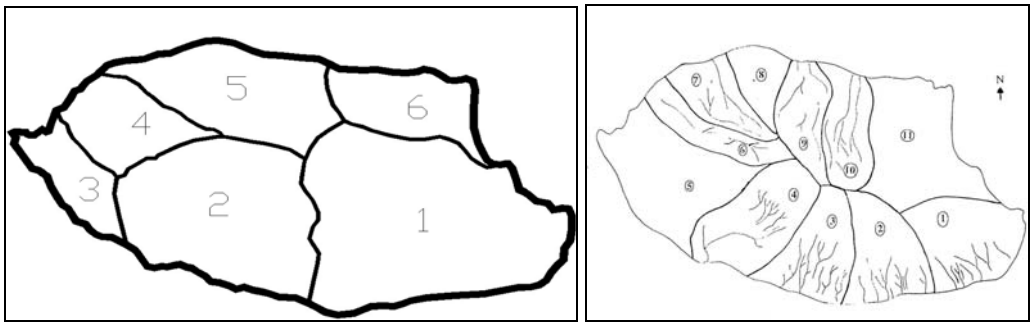

Figure 3: Watersheds (right) and Groundwater Basins (left) in Kish Island

Investigations of marl layer topography throughout the island show different groundwater storage potentials due to unevenness and slope the layers. In this regard, groundwater subbasins 1 and 2 receive the largest amount of infiltrated water with more than 60 percent. Subbasins 5 and 6 in northern part of the island have no groundwater aquifer. Finally, subbasins 3 and 4 in west part of the island store groundwater in the depressions existing on the marl layers.

SYSTEM OF QANAT IN KISH ISLAND

Kish Island inhabitants have tried to make maximum use of scarce water resources in any practical form. To make use of surface water resources several techniques have been incorporated including construction of Ab-Anbars (water stores), and dams and exploitation of springs. To do so, 6 ab-anbars, 5 dams and 3 springs have been applied. The outstanding feature regarding the dams is their dual purpose function. The dams, rather to controlling and storing the surface runoff to prevent them from evacuating to the sea, were used to facilitate recharge of groundwaters. Groundwater resources were exploited through digging of wells and construction of qanats.

The remarkable and think-worthy issue regarding the Kish Qanat system is its functioning mechanism. Typical qanats have been usually constructed to exploit the existing groundwater aquifers of the area. In all known qanats systems scattered throughout Iran, the main function is transferring water from upstream groundwater aquifers (wet part) to downstream areas (dry part). The conventional qanat galleries are run through permeable layers to be recharged by aquifers. Qanat wells have a dual purpose function including qanat gallery 1) maintenance and dredging, and 2) system ventilation. Kish qanat systems have been installed in places where no groundwater aquifer exists. Thereto, qanat gallery is not recharged from its surrounding since it is running through the impermeable marl layer. Longitudinal profiles of typical and Kish qanat systems are shown in figure 4.

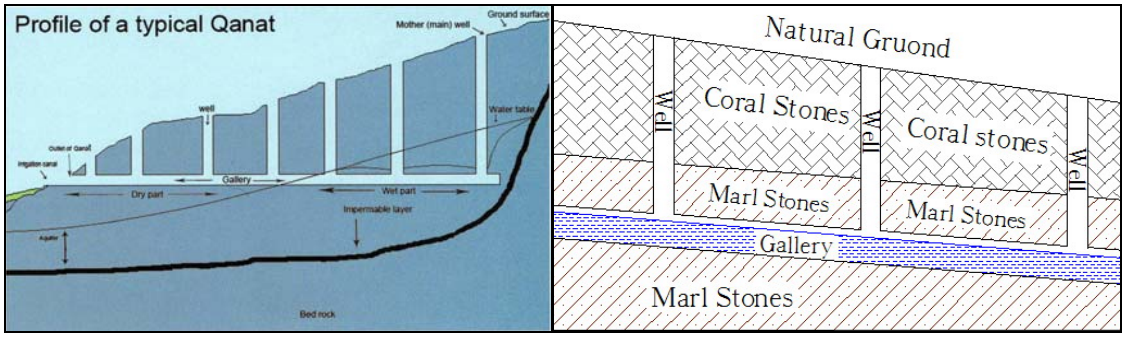

Figure 4: Longitudinal Profiles of Typical (left) and Kish (right) Qanat Systems

The Kish qanat system has been innovated by the island inhabitants to store the rainfall infiltrated fresh water since reliable surface and groundwater resources were not possible in the island due to its climatological and geological characteristics. The qanat gallery runs through an impermeable marl layer at a depth of about 4m. The marl layer lies underneath a permeable 2-10 m thick coral limestone layer. The qanat gallery receives rainfall water directly from the wells installed on it. It also receives the infiltrated rainfall into the coral limestone layer through its wells. The wells are located about 15 m apart. The gallery bed slope is very gentle considering looseness and vulnerability of the marl layer. Passage of qanat gallery through the impermeable marl layer prevents water losses through capillary rise and evaporation due to high temperature. Investigations show that there are about 9400 km galleries in four existing qanat strings with 611 wells in the island.

Water withdrawal had been performed through two methods. In the first method, similar to typical qanat operations, water was withdrawn from qanat wells or its outlet. However, the Kish inhabitants innovated another method to withdraw qanat water. They managed to dig special passages directing to marl layer depression where water had been stored along the qanat gallery. A typical profile of such passages and an 800-year old existing passage are shown in figure 5.

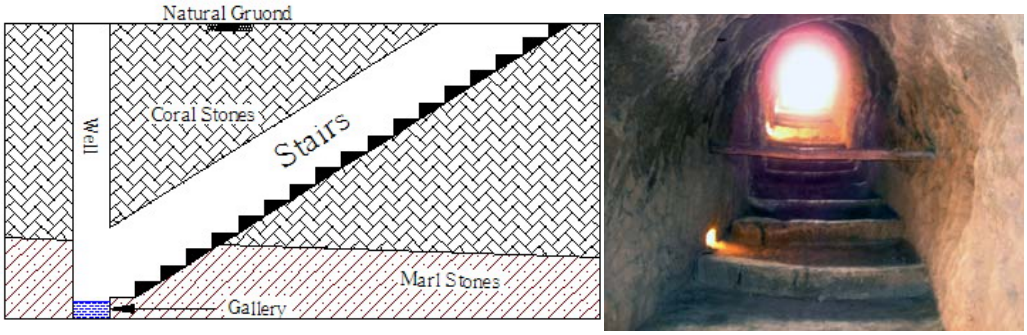

Figure 5: Typical Profile of an Access Path (left) and an 800-year old Access Path (right)

Unfortunately, due to obsolescence of the Kish Island form 2nd century the qanats were ill-considered or disconsidered thereafter. Hence, they were not properly maintained and as a result wells were filled up by debris and galleries were damaged. Interviews with some of old native inhabitants of the island indicate that they do lack a specific methodology to operate and maintain the qanat systems. However, considering the very long age of these qanats, their state of being so scattered, and their locations at upstream of most of agricultural and residential zones of the island one may highly recognize their importance and unique role and also their superiority on typical wells regarding the Kish island unique characteristics.

CONCLUSION

With no doubt, technology development in the ancient civilizations was an answer to mankind needs for optimum exploitation of natural resources, safety towards natural hazards and improvement of individual and social life standards. Man intention to control the environment and exploit its natural resources has resulted in opportunities and challenges leading to increase of his understanding of natural resources and materials and construction of structures. The Kish Island Qanat System is a significant proof to this claim. The 2300-2500-year old Kish Qanat System takes us into deep thinking since rainfall harvesting and groundwater recharging have just been taken into consideration in the past recent decades. Let's hope that specialists and engineers take proper lessons for correct management of natural resources and environment upon observing and studying such cultural heritages of the world along endeavoring to protect them.

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