OVERVIEW OF THE HYSTORY OF WATER RESOURCES AND IRRIGATION MANAGEMENT IN THE NEAR EAST REGION

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ABSTRACT

The Near East region extends from Turkey in the north to Somalia in the south and from Mauritania in the west to Afghanistan in the east. It is characterized by aridity and scarcity of water which explains its dependence on irrigation since ancestral times.
The aim of this paper is to give a brief overview of the history of water management and irrigation developments in the region, based on remnants and bibliographical research, with a focus on ancient water management techniques and ingenious irrigated agriculture practices, including the use of non conventional water resources. The implications and impacts of these techniques on modern management of water resources and irrigated agriculture are also discussed.

INTRODUCTION

In general terms, irrigation can be defined as the artificial supply of water to supplement natural precipitation – or substitute for it – for the purpose of agricultural production. In the Near East region, irrigation has been vital for as far back as history can go, making it the origin, or at least one of the origins, of irrigation practice and its diffusion to the rest of the world. The rise - and at times decline – of the different civilizations that lived in the region was related to water harnessing. Irrigated agriculture provided economic prosperity, social stability and military powers.
The early developments evolved gradually with time and provided the foundations for today's water technologies not only in the region but throughout the world. The historic heritage and the lessons learned provide a wealth of experience for the sustainable management of water resources today and in future generations.

IRRIGATED AGRICULTURE HISTORICAL DEVELOPMENTS

In many part of the region, ruins and historical remnants of ancient water structures and irrigation schemes, dating back to 2000-5500 B.C., can still be found. It is believed that elaborate water diversion structures and irrigation schemes (by the standards of those days) were developed and used in Egypt and Mesopotamia, as far back as 5000 B.C. The methods invented were refined with time and became gradually adopted by the surrounding regions, particularly North Africa and the Mediterranean.

The Practice of Irrigated Agriculture

According to many references, the major first civilizations that developed on the basis of irrigated agriculture were in the Near East region, particularly Egypt and Mesopotamia. The peoples of these civilizations were the first to learn that, among the tasks needed for growing crops and ensuring food production, the provision of water was a vital one. This constituted the first steps of harnessing water resources for irrigation which became later a technology underlying the success of the greatest civilizations of the Region.

Anthropological studies have revealed that the oldest irrigated agriculture in the Near East Region was practiced in Egypt some 5000 years B.C., and is as old as the practice of agriculture itself. Ancient Egyptians built large flat basins for growing crops along the Nile river banks. At the peak of floods, water was naturally diverted into these basins where it was stored in the fields for 40 to 60 days. The technique was rather primitive and passive as it depended on the Nile flood fluctuations, but allowed the production of winter crops[1]. The system was later refined and gave rise to basin irrigation, a productive adaptation of the natural rise and fall of the river. Farmers constructed networks of earthen banks, some parallel to the river and some perpendicular to it, forming basins of various sizes. Regulated sluices would direct floodwater into a basin, where it would sit for a month or so until the soil was saturated. Then the remaining water would be drained off to a basin down-gradient or to a nearby canal, and the farmers of the drained plot would plant their crops[2].

Similar techniques have also been used in Mesopotamia, some 3000-5000 years B.C. Compared to Ancient Egypt, Mesopotamia was supplied by the Tigris and the Euphrates which were much smaller than the Nile. The arable lands were very flat with the problems of poor drainage and soil quality, important flooding and excess of salts. The Euphrates bed, being higher than that of the Tigris, provided a natural gradient for irrigation and drainage schemes: the Euphrates water was used as supply, whereas the Tigris River provided a drain[3]. The flooded lands in between were used for growing crops.

In North Africa region, as in Egypt, Iran and Iraq, water management and irrigation practices are considered very ancient techniques. It is believed that development of irrigation in North Africa have extended from Mesopotamia and Egypt to the Mediterranean under the Carthaginian (Phoenician) some eight centuries before Christ and then to the south under the Roman Empire (146 - 439 B.C.). The focus of water management by the Romans in the region was on harnessing existing water sources and rainfall water collection. Some of the structures developed have been preserved and are still used nowadays for domestic and irrigation purposes; they include:

- Dams built with blocks of masonry established in wadi beds, with one of the sides left open as a derivation canal to serve irrigated lands;
- Reservoirs and cisterns filled by rainwater drained from mountains. These reservoirs were very numerous and at times had very important storage capacity;
- Canals and aquaducts for transporting natural sources of water as one of the Roman ingenious practices;
- Dams in dry stones, generally near mountains to divert water for irrigation.

During the early Islamic period, prosperity of the Abbasid Dynasty, headquartered in Baghdad (762 - 1258 A.D.), was partly related to water and irrigation management which concerned the renovation and extension of all existing irrigation schemes. Irrigation water was carried from the Euphrates at five separate points and led in parallel canals across the plains to the south of Baghdad[3]. In the 12th century, salinization problems increased and canals were silted because of the lack of maintenance. This, coupled with natural catastrophes particularly massive floods which shifted the courses of both the Tigris and the Euphrates, destroying most supply structures, contributed to the decline of the dynasty.

A similar trend followed in North of Africa between the eighth and the thirteenth centuries A.D., with intensive development of water and irrigation structures to boost agricultural production. Some of these structures are still functional today and include water lifting devices (noria or saniya, dulab, Diou or Dlou, Gargaz or shadoof), aquaducts, cisterns and qanats, as elaborated below.

Irrigation Water Infrastructure

Surface Water Diversion, Conveyance and Storage Systems

The first major irrigation project in Egypt was built about 3100 B.C., during the reign of Menes, founder of the First Egyptian Dynasty[1]. By 2100 B.C., several ingenious systems for irrigation were in use in Egypt, including one with about twenty kilometers of canal that diverted Nile floodwaters to lake Moeris[1]. The oldest dam in the region, named Sadd Al-Kafara, was built on “Wadi Al-Garawi” during the period of the Third or Fourth Dynasties of Pharaohs (between 2686 and 2498 B.C.)[4][5], but it was

washed out by floods before it was ever used. Across the Red Sea, the oldest dam in the Arabian Peninsula, Marib Dam, in Yemen today, was built about 500-600 B.C.
In Mesopotamia, very large weirs and diversion dams were built, to create reservoirs and to supply canals that carried water over considerable distances across flat areas. The scale of their irrigation was larger than in Egypt, and Mesopotamian irrigation was active and based on water interception. It is believed that the oldest technique of surface water management by building diversion dams was first realized in Mesopotamia.
Irrigated agriculture in Mesopotamia has been practiced for more than 5000 years. The City of Eridu, located about 22 km south of Nasiriya and 40 km south west of the traditional site of the Garden of Eden (Mughair), is believed to be one of the first villages of Mesopotamia that grew into cities as a result of irrigated agriculture development (Photograph 1). The region flourished later on during the period of the Babylonian dynasty, especially under the rule of the famous King Hamourabi (1792-1750 B.C.) The well known Hanging Gardens of Babylon – one of the Seven Wonders of the World - are believed to have been built during the Neo-Babylonian Dynasty, under the king Nebuchadnezzar (604 -562 B.C.)
The Solomon's Pools in Bethlehem, Palestine, are three large catchment reservoirs of around 160,000 m^3 each, built with stone and masonry between 2000 B.C. and 30 E.C. in two stages. Ancient aquaducts used to collect water from the springs of Wadi Arab and Wadi Biyar and carry it to the pools. Some of the springs with channels are still in operation and are used for irrigation.
Water diversion devices for irrigation and other purposes have been used in various locations in the region, particularly Egypt, Yemen, Iraq, Iran and North Africa. In Egypt, the Al-Kafara dam was located 30 kilometers south of the current Cairo, between "Wadi Al-Hof" and "Wadi Al-Garawi". Its construction required the excavation and transport of approximately 100,000 cubic meters of rock and rubble[4], for an estimated capacity of 600,000 m^3 of water[6]. In Yemen; the oldest dam was built near Marib, the ancient Sabaean capital, in 500-600 BC. Constructed in masonry over a length of about 500 m[1], the dam had the objective of holding back some of the annual flood waters of Wadi Dhâna and to divert them into two canal distribution systems of irrigation use.
In North Africa, at the beginning of the 12^{th} century, several terraces and dry stone dams were constructed to divert surface water to be used for irrigation, notably in arid regions.
In Madeira Island (Cyprus) about 1.5 km network of irrigation channels carried spring water down from nearby mountains. Paths and steps were built alongside the man-made water channels for maintenance purposes. In Lapta (Lapithos), many springs from the Besparmak Mountains flowed noisily along irrigation channels to supply the surrounding gardens and groves of citrus and olive. The Kamares aquaduct was built in the 18^{th} century on the outskirts of Larnaca for domestic and irrigation purposes.
The exact date of the invention of early diversion dams is not well known, but it is clear that the technique started in the Near East region. Early civilizations had a clear distinction between storage and diversion dams. The latter seems to have a long history in Yemen and explains the early water and irrigation management philosophy. It was preceded by early irrigated agriculture production that relied on natural floods events during rainy seasons.

Groundwater Mobilization Systems

The Persians started constructing elaborate systems for extracting groundwater in the dry mountain basins of Iran and in western Persia, northern Mesopotamia and eastern Turkey, about 2,500 years ago[7]. The system consisted of tapping groundwater by a series of wells, 20 to 30 meters apart, connected at their bottoms by a tunnel with controlled slope (Photograph 7). The upstream wells tap groundwater and the series of all wells represents points of entrance for excavation and maintenance workers. This technique has the advantage of using milder slopes than surface canals and preventing evaporation losses; but the main advantage reside in taping groundwater without lifting devices. The system, termed "qanat", system induced prosperity of water users by developing irrigated agriculture. It also allowed the creation of numerous oases in desert areas.
The history of qanat diffusion from Persian origin to other countries of the region can be summarized as follows[1]:

- During the period 550-331 B.C., when Persian rule extended from the Indus to the Nile, qanat technology spread throughout the empire[1]. The rulers provided a major incentive for qanat builders and their heirs by allowing them to retain profits from newly constructed units for five generations. As a result, the system expanded westward from Mesopotamia to the Mediterranean, southward into parts of Egypt and east of Persia in Afghanistan, the Silk Road, oases settlements of central Asia, and Chinese Turkistan[8].
- During Roman-Byzantine era (64 B.C. to 660 A.D.), large numbers of qanats were constructed in Syria and Jordan. The Romans also used qanats as subterranean parts of aquaducts, as witnessed by still examples of "qanat-aquaduct" system in Tunisia and Turkey.
- The expansion of Islam provided another major diffusion of the technology, spreading qanats westward across North Africa and into Cyprus and Sicily.

The technology of qanat was rapidly spread throughout the Middle East and North Africa under different names, but the basic principles remained the same (Box 1).

Water Conservation Systems

Throughout the highlands of the Near East region, ancient farmers have laboriously constructed small terraced fields by filling horizontal plots with soil behind stone walls. The terraces allowed storing direct precipitation and runoff from upstream for use by crops. In a second stage of technological development, the fields are watered by complicated systems of open channels and wooden aquaducts leading from nearby rivers or tributary streams. Later on, intricate irrigation systems were developed, by dividing the terraced fields into small shallow basins that were irrigated in turn.

This technique, consisting of rock-walled bench terraces and diversion of rainfall water, has been used in Lebanon nearly 3000 years ago, for irrigating the famous forests of cedar. Similarly, Yemen is well known for its ancient terraces that facilitate the successful cultivation of crops on very steep terrain (Photograph 4). Throughout North Africa, inhabitants have developed elaborate systems for harvesting rainfall water to irrigate trees. The "Djessure" technique, built in runoff courses in Tunisia, is an example of such systems that is still widely used today and allows growing olive and other tree species in areas where rainfall is less than 250 mm per year.

Another ingenious system of water conservation in agriculture, believed to have originated in North Africa, is the "pot-watering" or "jar irrigation". It consists of burying a water-filled clay jar near a tree seedling so that water potential gradient across the jar wall allows moisture movement to provide water for the plant roots. The system is still used today to grow trees for fixing sand dunes in the Tafilalet region, south of Morocco.

Water Lifting Devices

The Egyptian "shadoof" and the water wheel or "noria" or "sania" are probably among the earliest devices for lifting water to be used for irrigation and domestic water supply. The shadoof (Photograph 2) consisted of a bucket – leather bag in ancient times - balanced with a counterweight that served for lifting water from the Nile river. In North Africa, a similar technique (called locally Diou or Dlou) was developed in the beginning of the 12th century[12]. It consists of a leather bag connected to a rope that serves for lifting water from wells. The system was refined later on with the introduction of a pulley and animal traction for lifting water from deep wells. It is still used widely today for providing drinking water and irrigating small land plots close to wells. The device was also diffused to the Arabian Peninsula.

Box 1: Development and spreading of qanat systems

The "Qanat" technique is still in use in Iran for various purposes including irrigation. Out of an estimated total of 40000 units, 70% are operating particularly in Bam, Yazd and Isfahan. Many other units have collapsed as a result of neglect and earthquakes, such in Baravat and Bam.

The principle of qanat has been established up to 2,000 years ago in the Arabian Peninsula under the name of "Falaj, plural Aflaj". The systems provided ancient Arabians with permanent and stable water for drinking and food production. Their number dwindled with time, with some units still operational today. Several existing oases, such as those of Mahdah, Oman, depended entirely on this system for their water needs. The social structure and water rights in these isolated communities were closely linked to the need for managing and maintaining these systems in an optimal manner.

In Saudi Arabia, there is evidence that a Falaj once saved the city of Jeddah from a Portuguese invasion in 1516 A.D. The sixteen kilometers Falaj supplied the town with all water needs during the invasion. In the United Arab Emirates, the well-preserved Al-Mualla falaj around Al Ain city dates back to the Iron Age. The majority of Aflaj in the Arabian Peninsula existed where Oman lies today with an estimated number of 11,000 units out of which some 4,000 were major ones, constantly flowing and constituting the main source of water. Today they deliver around 900 Million cubic meters of water per year, representing 70% of the country's total water use and irrigating 55% of the total farm lands under irrigation.

In Afghanistan the systems, termed "Kareezes", are still widely used, with about 6500 units supplying 168000 hectares of land (7% of the total irrigated area). Similarly, Persian wheels still supply water for drinking purposes and for irrigating about 12000 hectares of land[9].

In Syria, qanats have been used to irrigate fields and gardens for centuries, particularly around the cities of Damascus, Selemiya, Palmyra, Qadeym, and Taibe. The diversity of qanat types seems to reflect their origins, but it is certain that many of the systems were first constructed during the Roman-Byzantine era (64 B.C. to 630 A.D.) The large number of aquaducts and wells, many of which are still in use, generally improved irrigation techniques and expanded arable land[10]. Today, Syria has a total of 239 qanat galleries, but only 12% still flow and most are gradually drying up.

In Jordan, the technologies of qanats and cisterns have also been used since ancient times, particularly the Roman-Byzantine era. In the Jordan Valley six qanats were rehabilitated in the 1920s and used for irrigating about 600 hectares. In the early 1960s, farmers in the region began installing diesel-pumped wells which resulted in drying up all qanats by 1970. In the West Bank of Palestine, since more than 2000 years, farmers have irrigated terraces of olive trees, vineyards, and orchards with water tapped from some 250 qanats crossing through the hills on the eastern shores of the Mediterranean. Today these terraces and tunnels are largely abandoned.

In North Africa, the qanat system was introduced after the Arab Expansion and became widely adopted by the 13th Century. Called "Foggara" or "Damous" in Tunisia, it has been used in El Guettar region (Orbatta Mountain) to irrigate small oases and in the north, near Tunis, for irrigation and domestic use. In Algeria, the system termed "foggara" has been widely used for irrigation, particularly in the south west, for more than 600 years. The installed systems provided water for irrigating more than 25000 hectares of oases in the region of Ouled Said in Adrar. Many of these systems have dried out and sustainability of the few remaining ones will depend on their maintenance and the level of groundwater. In Morocco, the system, called "Khettara", was introduced in many localities, particularly around the city of Marrakech and the Tafilalt region. In the latter, the network provided domestic water for the ancient city of Sijilmassa and for irrigating about 3000 ha[11]. Many systems continued operating for much of the northern oasis until the early 1970s. Today, only 19 khettaras with 90 km of network are sill supplying 12 localities.

The qanats of southern Morocco (Marrakech and Tafilalet) and southern Algeria represent the greatest development of this technology outside the Persian area[1].

It is worth mentioning that a wealth of knowledge on groundwater abstraction was written back in the 10th Century A.D. by the Persian scientist Karaji. His book titled "The Extraction of Hidden Waters" deals with the techniques of groundwater exploration and is in general agreement with modern understanding of the subject [18].

The Noria or Egyptian Wheel (Photograph 3) is thought to be the first vertical water wheel and was invented by the Romans around 600-700 B.C. It consists of a wooden wheel powered by water and fitted with buckets that lift water for irrigating nearby lands. The diffusion of the noria is typically associated with the Arab civilization and the animal-powered noria is considered as the high symbol of the Islamic imprint upon irrigation technology. The hydraulic wheel was first built in Fez, Morocco, in the 13th century[13] then spread to other parts of North Africa. Waterwheels powered by camels have been used in Afghanistan and elsewhere in the region to lift water for irrigation and domestic use (Photograph 5). A limited number of these units is still in use today. In Sudan ox-powered system, as a simple irrigation device, has been used for centuries and continues nowadays.
A different version of the noria is the Persian Wheel the date of its invention is not well known. It consists of an endless series of pots of unequal weight turned over two pulleys [16] and is therefore classified as a pump rather than a water wheel. The water wheel, in its different versions, constitutes the ancestor of water pumps and modern hydropower systems the principle of which is to extract power from the flow of water. The shortage of labour during the Middle Ages made machines, such as the water wheel, cost effective. The water wheel remained competitive with the steam engine well into the Industrial Revolution [17].
The system used for lifting water to irrigate the Hanging Gardens of Babylon remains a mystery, although Greek historians describe it as consisting of something similar to an Archimedes' screw or of chain pumps, each consisting of two large wheels, powered by slaves.

Water Regulations

The first known regulations related to water date back to the era of the Babylonian King Hammurabi (1792-1750 B.C), with the elaboration of a code of law based on previous Sumerian laws. Considering the importance of farmers' cooperation as critical in irrigation management, to ensure a fair distribution of water and to avoid conflicts, the Code introduced three main concepts related to irrigation water management: 1) proportional distribution whereby the farmer receives water in proportion to the amount of land he works; 2) definition of an individual farmer's responsibility towards the whole community, by safeguarding the sections of public canals that lie on his property, accepting community rules such as water turns and liability for damages caused to neighbours owing to negligence or malice; 3) water apportionment and policing of irrigation arrangements as a collective responsibility of beneficiary farmers. These concepts constituted the foundations of irrigation development in the region, and although some of them have been neglected during certain periods of time, many countries are returning to them today as a way of ensuring good management through farmers' participation.
These early water-related regulations were followed by a wealth of other laws, at times very elaborate and complex, throughout the region.
As an incentive to encourage the construction of agricultural hydraulic works, the Romans (146-438 B.C.) allowed the lands that bear such works to be transmitted to the heirs of the persons who constructed them. Similarly, during the period 550-331 B.C., the Persian rulers encouraged by law qanat builders by allowing their heirs to retain profits from newly constructed units for five generations.

Water Distribution and Monitoring Devices

Because of the link between the Nile's flow level and the population's well-being, the ancient Egyptians developed a system for monitoring the Nile flow in many points along the Nile River. The system (Nilometer) consisted of marking the level of water and comparing it with those of previous years, thus allowing predictions with some accuracy of the following year's high mark. At least 20 "nilometers" were spaced along the river, and the maximum level of each year's flood was recorded in the palace and temple archives[14]. The early version of the system consisted of marked flights of stairs and has been used for thousands of years (Photograph 6). It is not much different from the principle of today's river staff gauging.
At the beginning of the 13th century, Ibn Shabbat (1221-1285 A.D.), a Tunisian distinguished historian,

magistrate and engineer invented an elaborate system for water distribution in the Tozeur Great River. The system is still operating and well maintained. In Algeria, a system termed “Kassria” was used to distribute the flow of water from foggaras in an equitable way; the system is still operational in several oases. Many other ingenious water distribution systems and regulations, dating to several centuries back, are widely used for managing perennial and flood waters throughout the Middle-East and North Africa Region.

IRRIGATION WITH NON CONVENTIONAL WATER RESOURCES

There are no historical records of the use of saline and brackish water for irrigation in the early civilizations of the Near East. Nevertheless, the loss to salinization of large areas of agricultural lands in Mesopotamia and other parts of the region provides an indication that saline waters were used for agricultural production. It is very likely that, when available, such low quality water has been used especially under the shortage of good quality water such as during drought periods.

There is also no historic indication however on the use of human wastes in the region. In the absence of sewage facilities, it is likely that such wastes were disposed in open lands and water courses, thus contributing to soil fertility. Remnants of the first sewerage systems in the region have been found in the Roman ruins, as Roman cities had regular systems of drains running under the streets and carrying storm water and sewage. Individual and public toilets have also been found.

A few centuries later, there was renewal interest in the construction of storm sewers, mostly in the form of open channels or street gutters in cities. The development of municipal water supply systems and household plumbing brought about flush toilets and the beginning of modern sewer systems. In the beginning of the 20th Century, septic tanks were introduced as a means of treating domestic sewage from individual households both in suburban and rural areas in the Near East Region. The construction of sewage treatment facilities started around the same time.

The concept of treating and recycling sewage effluent, as known today, is recent in most Near East countries. However, untreated sewage has been used around old inland cities, such as Damascus, Fez and Marrakech, for several centuries[15]. The wastes were dumped into rivers where they mixed with fresh water and were used in the outskirts of cities for irrigating fruit trees and vegetables.

The interest in using municipal wastewater grew in recent years in all Near East countries as a result of freshwater shortage but also for environmental concerns. The number of wastewater treatment plants has grown rapidly over the last few years and continues to hike in many countries. However, the high cost of sewerage systems and treatment plants are hindering the generalization of these technologies to all population of the region. As a result, the picture of wastewater treatment and reuse is very heterogeneous, ranging from discharge – and at times even direct use - of raw sewage to high level quality treated effluent. The situation is likely to improve gradually with improvement in economic and social development, greater shortage of freshwater and increased awareness on health and environment.

CONCLUSIONS

As witnessed by historical and archaeological records, irrigation has been practiced in the Near East Region for more than 5,000 years. In fact, harnessing water resources and mastering their use were the backbones of development and prosperity of most early civilizations in the region. Dependence on irrigation for food production, social stability and power gradually improved the knowledge of early civilizations to manage water for agricultural use. The earliest irrigation practice seems to have started in Egypt, with flood water from the Nile River, before gradually evolving to the use of water lifters powered by humans, animals and the flow of water. The technique of artificial irrigation was later on introduced in Mesopotamia and Iran, at least 3500 ago, before spreading to different neighboring regions, particularly westward to North Africa and the Mediterranean.

While there is no doubt that irrigation development greatly enhanced economic development, attempts to evaluate the technical performance and impacts of ancient water technologies in the region reveal that the task is very complex. The infrastructure and its evolution with time indicate that the degree of

hydraulic genius was high during all historic periods. Water management was based on simple rules of physics and the devices developed were labour intensive but they constituted the basic foundations for the technologies of today.

The traditional structures and practices for water management obeyed to certain criteria specific to the regions of their application. For instance, qanats were constructed essentially in regions receiving between 100 and 300 mm as average annual precipitation and all qanats were found below the 500 mm isohyet line. Moreover, the structure and practices were compatible with water resources sustainability as compared with today's technologies. This is particularly true when comparing the impact of qanats on groundwater with the use of pumps and tube wells. In fact, groundwater overdraft through pumping is the major cause for the abandonment of qanats in most parts of the region. However, the practice of irrigation in old times has not always been without risk for agricultural lands, as witnessed by the loss to salinization of large areas in Mesopotamia and other parts of the region.

Collective water management is another main characteristic of ancient civilizations in the region. This was probably due to the fact that water structures and practices were labour intensive and beyond the capacity of individuals. Today, governments are attempting to go back to collective management, through the involvement and active participation of farmers.

The role of governments was detrimental in ancient civilizations for developing water resources for all uses, particularly agriculture, by providing incentives to beneficiary populations and establishing and enforcing well adapted regulations.

The technological developments over time constituted unavoidable stages for reaching the current level of know-how and should not be ignored. Unfortunately, it is not often that modern management takes into account the lessons learned and the wisdom of managing natural resources developed and accumulated by our ancestors.

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Photo 1: Ruins of Eridu, Iraq (source: www.atlas.net)

Photo 2: Egyptian Shaduf (source: www.waterhistory.org)

Photo 3: Noria in Hama, Syria
(source www.angelfire.com)

Photo 4: Terraces in Yemen

Photo 5: Camel powered water wheel, Afghanistan
(source: www.hindunet.org)

Photo 6: Nilometer on Elephantine Island, Aswan
(source: www.waterhistory.org)

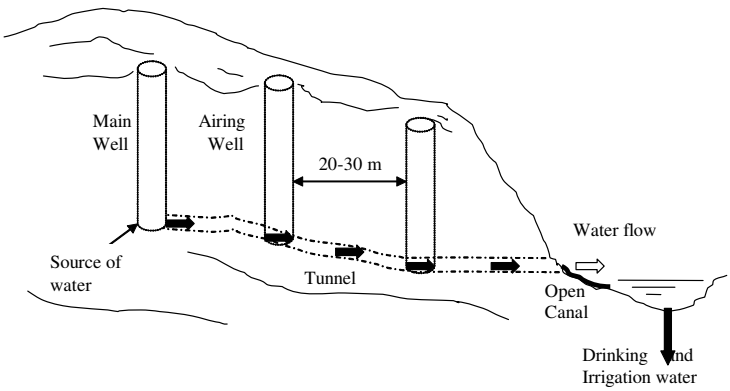

Photo 7: Principle of qanat conception[19]