The Ingenious Ancient Qanats of Iran
On UNESCO List of World Heritage

A traveler flying over Iran can see plainly that the country has an arid climate. Most of Iran (excepting areas in the northwestern provinces and along the southern shores of the Caspian Sea) receives six to 10 inches of rainfall a year. Other regions of the world with so little rainfall (for example the dry heart of Australia) are barren of attempts at agriculture. Yet Iran is a farming country that not only grows its own food but also manages to produce crops for export. It has achieved this remarkable accomplishment by developing an ingenious system for tapping underground water called Qanat.
Qanat is one of a series of well-like vertical shafts, connected by gently sloping tunnels creating a reliable supply of water for human settlements and irrigation in hot, arid, and semi-arid climates. The qanat technology is known to have been developed by the Persians sometime in the early 1st millennium BC and spread from there slowly westward and eastward to many regions of the world such as Sinkiang, Western China (e.g. Turfan oasis), Southwestern Afghanistan, Southwestern Turkmenistan, the Arab world, Libya (e.g. Zella), Tunisia, Algeria (e.g. Germa), and Morocco; and were introduced by the Romans into Egypt and Syria, and into Southern Spain by the Moors.

Inside qanats, there are wonders unbelievable to modern world. According to the Iranian Ministry of Energy, the number of operating qanats in Iran is about 36,300. The average length of these qanats is about 6 kilometers and the average depth of all shaft wells of a Qanat together is some 4 kilometers. The most important of these qanats are the UNESCO World Heritage Site of Ghasabe Qanat of Gonabad in Khorasan Province and the 3000-year-old, Zarch Qanat of Yazd Province. Yazd, Khorasan and Kerman are the known for their extensive system of qanats.

Ghasabe Qanat

Located in Gonabad city of Khorasan Province, the UNESCO World Heritage Site has 427 water wells with a length of 33113 meters and has been constructed based on different sciences like physics, geology and hydraulics and made it possible for the inhabitants to live in such a dry land that it rains there scarcely. The 2700-year-old Qanat still provides drinking and agricultural water to approximately 40,000 people today. Its main well depth is more than 360 meters and its length is 45 kilometers.

Zarch Qanat

The 3000-years-old Zarch Qanat featured for its square section, is the world's longest and one of the country's most ancient Qanats. Being a plain qanat with a gallery length of 80 km (with branches), it has 2115 shafts and a mother well of 80 meters deep, 4 meters of which is inside the underground aquifers. It is still active in the face of severe decline of the aquifer.

Mun Qanat

Probably the most wondrous Qanat in the world is the 2-story Qanat of Mun in city of Ardestan city of Isfahan Province. This Qanat has two main tunnels located above each other with 3 m difference in elevation. There is no leakage between the two tunnels due to the impermeable layer between the two tunnels. This Qanat has two mother wells, one for each of the tunnels. The top tunnel goes through a half circle path when it reaches the vertical shafts. This Qanat is 2 kilometer long, has 30 shafts and discharges 60 liters per second.

Vazvan Qanat

The 65-km-long qanat located to the south of Kashan City of Isfahan Province in the Central Plateau of Iran, this Qanat is 1800 m long and has 64 wells with a mother well of about 18 m deep. The qanat's most
important feature are its underground dams. There are three dams constructed along the main tunnel that can block the water flow during winter. The dams are almost 16 m high and 1.5 m wide. There are also 6 gates in different levels of the dam body, so that based on the level of the groundwater during spring and summer, the appropriate gate will be opened.

Moreover, as there is no need for the Qanats’ water in winter, the water is stored to be used during spring and summer. This will provide more water for agricultural use during spring and summer and also, this helps recharge the groundwater.

**Kish Qanat**

Dating back to 2000 years ago, the qanat is located in Kish Island, south of Iran. It’s 17 km long and has 274 wells and the walls is covered with fossils of sea creatures. In some points along the main tunnel, the diameter of the tunnel increases to 10 m. This Qanat is now rehabilitated and has turned to a popular tourist attraction.

**Qanat Technical Features**

The Qanat system consists of underground channels that convey water from aquifers in highlands to the surface at lower levels by gravity. The Qanat works of Iran were built on a scale that rivaled the great aqueducts of the Roman Empire. Whereas the Roman aqueducts now are only a historical curiosity, the Iranian system is still in use after 3,000 years and has continually been expanded. There are some 36,300 Qanat units in Iran, comprising more than 350,000 km (about the distance between the moon and the earth) miles of underground channels. The system supplies 75 percent of all the water used in that country, providing water not only for irrigation but also for house-hold consumption.

Discoveries of underground conduits in a number of ancient Roman sites led some modern archaeologists to suppose the Romans had invented the Qanat system.

Written records and recent excavations leave no doubt, however, that ancient Iran (Persia) was its actual birthplace. As early as the seventh century B.C. the Assyrian king Sargon II reported that during a campaign in Persia he had found an underground system for tapping water in operation near Lake Urumieh. His son, King Sennacherib, applied the “secret” of using underground conduits in building an irrigation system around Ninevah, and he constructed a Qanat on the Persian model to supply water for the city of Arbel.

Egyptian inscriptions disclose that the Persians donated the idea to Egypt after Darius I conquered that country in 518 B.C. Scylax, a captain in Darius’ navy, built a Qanat that brought water to the oasis of Karg, apparently from the underground water table of the Nile River 100 miles away. Remnants of the Qanat are still in operation. This contribution may well have been partly responsible for the Egyptians’
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friendliness to their conqueror and their bestowal of the title of Pharaoh on Darius. References to Qanat systems, known by various names, are fairly common in the literature of ancient and medieval times. The Greek historian Polybius in the second century B.C. described a Qanat that had been built in an Iranian desert “during the Persian ascendancy.” It had been constructed underground, he remarked, “At infinite toil and expense … through a large tract of country” and brought water to the desert from sources that were mysterious to “the people who use the water now.” The methods used in Iran today are not greatly different from the system devised thousands of years ago. The project begins with a careful survey of the terrain by an expert engaged by the prospective builders. A Qanat system is usually dug in the slope of a mountain or hillside where material washed down the slope has been deposited in alluvial fans. The surveyor examines these fans closely, generally during the fall, looking for traces of seepage to the surface or slight variations in the vegetation that may suggest the presence of water sources buried in the hillside. On locating a promising spot, lie arranges for the digging of a trial well.

Two diggers, called muqanni, take up this task. They set up a windlass at the surface to haul up the excavated material in leather buckets and proceed to dig a vertical shaft about three feet in diameter, one man working with a mattock and the other with a short-handled spade. As they load the spoil in the buckets, two workers at the surface pull it up with the windlass and pile it around the mouth of the shaft. If luck is with them, the diggers may strike an aquifer at a depth of 50 feet or less. Sometimes, however, they dig down 200 to 300 feet to reach water, and this necessitates installing a relay of windlasses at stages 100 feet apart on the way down. When they arrive at a moist stratum - a potential aquifer - the diggers scoop out a cavity to its impermeable clay bottom, and for the next few days the leather buckets are dipped into the hole periodically to measure the rate of accumulation of water in it. If more than a trickle of water is flowing into the hole, the surveyor can conclude that he has tapped a genuine aquifer. He may then decide to sink more shafts into the stratum in the immediate area to determine the extent of the aquifer and its yield. The surveyor next proceeds to chart the prospective course of an underground conduit through which the water can flow from this head well or group of wells to the ground surface at some point farther down the slope. For the downward pitch of the conduit he selects a gradient somewhere between one foot in 500 and one in 1,500; the gradient must be slight so that the water will flow slowly and not wash material from the bottom of the conduit or otherwise damage it. For his measurements the surveyor uses simple instruments: a long rope and a level.

Consequently, the surveyor must determine the depth from the surface for each of these shafts. He uses a level to find the drop in the ground slope from each shaft site to the next and marks the length of this drop on the rope. This tells him how far down from the surface each shaft would have to be dug if the conduit ran a perfectly level course. He then calculates the additional depth to which each should be dug (in view of the prospective pitch of the conduit) by dividing the total drop of the conduit from the well’s water level to the mouth by the number of proposed ventilation shafts. Once the muqanni proceeds to dig the conduit itself, guide shafts are sunk to the indicated depths at intervals of about 300 yards to provide information regarding the route and pitch of the conduit for the diggers. They start the excavation of the conduit from the mouth end, digging into the alluvial fan. To protect the mouth from storm-water damage they often line the first 10 to 15 feet of the tunnel with reinforcing stone. The conduit is about three feet wide and five feet high. As the diggers advance they make sure they are following a straight course by sighting along a pair of burning oil lamps. They deposit the excavated material in buckets at the foot of the nearest ventilation shaft, and it is hauled up by their teammates above. The tunnel needs no reinforcement where it is dug through hard clay or a coarse conglomerate that is well packed. When the muqanni come to a boulder or other impassable obstacle, they turn around it and then must recover their bearing toward the next ventilation shaft. They show a good deal of skill in this, relying partly on their sense of direction and partly on listening for the sounds of the diggers
working on the vertical shaft ahead. Gases and air low in oxygen also are hazards; the diggers carefully watch their oil lamps for warning of the possibility of a suffocating atmosphere. As the muqanni approach the aquifer they must be alert to another danger: the possible flooding of the tunnel by a sudden inrush of water. This hazard is particularly great at the moment of breakthrough into the head well; the well must be emptied or tapped very cautiously if the men are not to be washed down the conduit by a deluge. Because of these hazards muqanni call the Qanat “the murderer.” A muqanni always says a prayer before entering a Qanat, and he will not go to work on a day he considers unlucky. Depending on the depth of the aquifer and the slope of the ground, Qanats vary greatly in length; in some the conduit from the head well to the mouth is only a mile or two long, and at the other extreme one in southern Iran is more than 18 miles long. Commonly the length is between six and 10 miles. The water discharge obtainable from individual Qanats also varies widely. For example, of some 200 Qanats in the Varamin plain, southeast of Tehran the largest yields 72 gallons per second and the smallest only a quarter of a gallon per second. Not until the Qanat has been completed and has operated for some time is it possible to determine whether it will be a continuous “runner” or a seasonal source that provides water only in the spring or after heavy rains. Because the initial investment in construction of a Qanat is considerable, the owner and builders often resort to probing and laborious devices to enlarge its yield. For example, they may extend branches from the main conduit to reach additional aquifers or excavate the floor of the existing conduit in order to lower it and tap water at a deeper level. A great deal of care is also given to the maintenance of the Qanat. The ventilation shafts are shielded at the top with crater-like

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walls of spoil and sometimes with hoods to prevent the inflow of damaging storm waters. Muqanni are continually kept employed cleaning out silt that is washed into the conduit from the aquifer, clearing up roof cave-ins and making other repairs.

As is to be expected of a system that has existed for thousands of years and is so important to the life of the nation, the building of Qanats and the distribution of the water are ruled by laws and common understandings that are hallowed by tradition. The builders of a Qanat must obtain the consent of the owners of the land it will cross, but permission cannot be refused arbitrarily. It must be granted if the new Qanat will not interfere with the yield from an existing Qanat, which usually means that the distance between the two must be several hundred yards, depending on the geological formations involved. When the parties cannot agree, the matter is decided by the courts, which normally appoint an independent expert to resolve the technical questions at issue.

Similarly, there are traditional systems for the fair allocation of water from a Qanat to the users. If the Qanat is owned by a landowner who has tenant farmers, he usually appoints a water bailiff who supervises the allotment of water to each tenant in accordance with the size of the tenant’s farm and the nature of the crop he is growing. When the peasants themselves own the Qanat, they elect a trustworthy water bailiff who sees that each farmer receives his just share of the water at the proper time - and who receives a free share himself for his service.

The bailiff is guided by an allocation system that has been fixed for hundreds of years. For instance, three hamlets in the region of Selideh in western Iran still receive the shares that were allotted to them in the 17th century by the civil engineer in the reign of Shah Abbas the Great. The hamlets of Dastgerd and Parvar are entitled to eight shares apiece and Karton nine shares and these allocations are built into the outlets from the Qanat distribution basin: the outlets at Dastgerd and Parvar are eight spans wide and the one at Karton is nine spans wide.

Whatever the future of Iran’s Qanat system may be, it stands out today as an impressive example of a determined and hardworking people’s achievement. The 22,000 Qanats in Iran, with their 170,000 miles of underground conduits all built by manual labor, deliver a total of 19,500 cubic feet of water per second - an amount equivalent to 75 percent of discharge of the Euphrates River into the Mesopotamian plain. This volume of water production would be sufficient to irrigate three million acres of arid land for cultivation if it were used entirely for agriculture. It has made a garden of what would otherwise have an uninhabitable desert. There are indications that in early times the country had flourishing vegetation that gradually dried up, partly because of deforestation and the loss of fertile soil by erosion.

The Persian people responded to potential disaster with a farsighted solution that is a classic tribute to human resourcefulness.

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Manuscript of the deed for endowment of the Qanat at Tehran’s old Shemiran Gate, by Alireza ibn Mohammad Etemad ul-Doleh Shirazi (14th Century A.H.) available at the treasury of the Library, Museum & Documentation Center of the Islamic Consultative Assembly under registration No. IR2805.
Entrance to the Library, Museum and Documentation Center of Islamic Consultative Assembly, Baharestan, Tehran.