

Water Works Through Four Millenia in Turkey

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Abstract Turkey is one of the foremost open-air museums of the world with regard to historical water works from the last 4000 years. Some of them are still in operation after several centuries or even several millennia. There are remains of dams, irrigation canals, and water collection structures dating back to the IInd millenium BC, the Hittite period in Central Anatolia. Several dams, irrigation canals, qanats date back to the first half of the Ist millenium BC, the Urartu period in Eastern Anatolia. Long-distance water conveyance systems, pipes, masonry canals, inverted siphons, tunnels, dams date back to the second half of the Ist millenium BC and the Ist millenium AD, the Hellenistic, Roman and Byzantine periods in Western and Southern Anatolia. Some dams, canals, watermills date back to the 11th to 14th centuries, the Seljukide period in Central and Eastern Anatolia. Several dams, irrigation canals, long distance water conveyance systems date back to the 14th to early 20th centuries, the Ottoman period in Turkey. Based on this tradition from four millenia, the modern Republic of Turkey, founded in 1923, is continuing to develop her water resources. The South-eastern Anatolia Project, encompassing the Euphrates-Tigris basin in Turkey, is the most interesting example.

Keywords Historical · Water work · Hydraulic · Structure · Turkey

1 Introduction

A very large number of ancient hydraulic works exist in Turkey (Fig. 1). Several ancient water works from this four-millenia-long period are still in operation after several centuries or even several millennia.

They date back to the IInd Millenium BC, the Hittite period in Central Anatolia; to the first half of the Ist Millenium BC, the Urartu period in Eastern Anatolia; to the second half of the Ist Millenium BC and the Ist Millenium AD, the Hellenistic, Roman and Byzantine periods in Western and Southern Anatolia; to 11th to 14th centuries, the Seljukide period in Central and Eastern Anatolia; to 14th to early 20th centuries, the Ottoman period in Turkey (Öziş 1994,

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Fig. 2 Springwater collection chamber in Hattusha (photo:Ü.Öziş)

2.3 Irrigation

There are remains of several water conduits in ancient Hittite settlements and irrigation systems in Central Anatolia (Bildirici 1994, 2004; Bildirici and Bildirici 1996; D.S.İ. 2008).

3 Urartu Water Works

3.1 Dams

There are several small dams from the first half of the 1st Millenium BC, the Urartu period in Eastern Anatolia. These are located mostly on various watercourses flowing to Lake Van.

Some of them, like the 7 m high dam raising the level of the Lake Keşiş, those on Doni creek, are still in use. Kırcağöl dam near Adilcevaz, Süphan and Argıt dams near Muradiye, several small dams between Van and Hakkari are other remains (Garbrecht 1987a; Belli 1996; Öziş 1999; Bildirici 2004; D.S.İ. 2008).

3.2 Water Supply and Irrigation

The 56 km long Şamram canal (Fig. 3) supplied the Urartu capital Tushpa (Vankale). This canal dates back to 800 BC and is one of the oldest canals still in use. The Şamram canal irrigates, with very few modifications, about 2000 ha of land (Ögün 1970; Burney 1972; Garbrecht 1975; Belli 1997).

Remains of the Ferhat canal, conveying water from Lake Balıklı towards the western edge of the Iğdır plain, some other irrigation systems in Van area, might also date back to the Urartu period.



Fig. 3 Şamram canal near the Urartu capital Tushpa (Van) (photo:Ü.Öziş)

Some of the underground water conduits of Van, still partly in use, might also date back to this period and can be considered as predecessors of later qanats. Certain cisterns in this region appear to be of Urartu origin (Bildirici 2004; D.S.İ. 2008).

4 Hellenistic, Roman and Byzantine Water Works

4.1 Water Supply and Conveyance Schemes

Hellenistic, Roman and Byzantine long-distance water supply schemes in Western and Southern Turkey date back to the second half of the 1st Millennium BC and the first half of the 1st Millennium AD. Those from the roman and early byzantine periods are of special importance.

The long-distance water conveyances in the Aegean and Mediterranean regions of Turkey are very numerous and new discoveries add to the rich variety of them (Fahlbusch 1987a; Büyükyıldırım 1994; Öziş 1996; Wiplinger 2006a, 2013a, b; Tanrıöver et al. 2006; D.S.İ. 2008; Türk et al. 2010).

These systems include spring-water collection chambers; lead-, stone-, clay-pipes of various sizes; rock-cut and masonry canals; tunnels of over 2 m height; inverted siphons under up to 190 m pressure with lead-, to 155 m pressure with stone-pipes; aqueducts of up to 40 m height.

The 242 km long water conveyance system along the south-western slopes of the Istranca mountains in Thrace to İstanbul, constructed for the new capital of the late Roman Empire in 4th century AD, was by far the longest water conveyance system of ancient times (Çeçen 1996). Two aqueducts of this system, Mazul and the almost 1 km long Valens (Bozdoğan) (Fig. 4) aqueducts, were later used by several ottoman water conveyance systems, among others the Süleymaniye water conveyance by the great Sinan in 16th century.



Fig. 4 Valens (Bozdoğan) aqueduct in the East Roman / Byzantine capital Constantinople (İstanbul) (photo:Ü.Öziş)

The water conveyance to Phocæia (Foça) with 100 km length ranks among the longest roman conveyance systems (Öziş 1996; D.S.İ. 2008).

The multiple water conveyance systems to Pergamon (Bergama) (Fahlbusch 1987b; Garbrecht 1987b), to Smyrna (İzmir) (Weber 1899; Öziş et al. 1999; D.S.İ. 2008), to Ephesus (Efes) (Öziş et al. 1998, 2005, 2014b; Öziş and Atalay 1999; Wiplinger 2006a, 2010, 2013a, b; Acatay 2008; D.S.İ. 2008; I.W.A. 2012; Kreiner 2013) make these cities, besides Rome, Lyon and few others, among the most interesting examples of multiple urban water supply schemes in the antique world. The respectively longest systems display lengths of 65 km at Pergamon, 30 km at Smyrna, 42 km at Ephesus.

The water conveyance systems to Perge (Büyükıldırım 1994), Hierapolis (D.S.İ. 2008), Tralleis (Baykan and Tanrıöver 2006) are other, somewhat shorter multiple water conveyance systems in Anatolia.

The lead-pipe inverted siphon of the Madradağ water conveyance to Pergamon resists up to 190 m water pressure, the 3.3 km long stone-pipe inverted siphon of the Karapınar water conveyance to Smyrna resists up to 155 m water pressure. These were siphons operating under respective largest pressures in the antique world, dating back to the late centuries of the 1st millennium BC Hellenistic period. The stone-pipe inverted siphon of Aspendos is, with about 1.7 km length, the longest on arches in Turkey (Alkan et al. 2014).

The ruined aqueduct over Karkassos (Ilyas) creek of the Soma conveyance to Pergamon, would have had a height of 40 m, being the second highest roman aqueduct after Pont-du-Gard of Nîmes.

Among the other water conveyance systems of interest are those of 40 km to Samosata (İzmirilgil 1983); of Lamas-basin (36 km to Diocaeserea; 25 km to Elaiussa Sebaste and Korykos, 20 km to Olba) (Arısoy et al. 1987; Öziş 1996; D.S.İ. 2008; Murphy 2013); of 25 km to Side (İzmirilgil 1979; Büyükıldırım 1994; Grewe 1994); of 24 km to Amaseia (D.S.İ. 2008); of 22 km to Alabanda (Öziş et al. 1979a; Öziş 1991; D.S.İ. 2008); of 22 km to Magnesia (Baykan et al. 2001; D.S.İ. 2008); of 22 km to Tripolis (D.S.İ. 2008); of 21 km to Metropolis (D.S.İ. 2008); of 21 km to Patara (Baykan et al. 1997; Baykan and İşkan 2011; İşkan and Baykan 2013); of 17 km to Aspendos (Fahlbusch 1987c; Kessener and Piras 1997; Kessener 2001; Ortloff and Kassinos 2003); of 17 km to Sardes (D.S.İ. 2008); of 12 km to Alinda (D.S.İ. 2008).

Some shorter water conveyances attracted also international interest; such as Laodicea (Baykan 1999; Büyükkolancı and Şimşek 2006; D.S.İ. 2008; Alkan et al. 2014); Perge (Fahlbusch 1987d; Büyükıldırım 1994); Aphrodisias (Commito and Rojas 2010); Antiochia/Orontes (Döring 2012);

Oenoanda (Stenton and Coulton 1986; Coulton 1987; Baykan and Cantilav 1997; Alkan et al. 2014); Iassos (Tomasello 1991); Xanthos (Büyükıldırım 1994; Burdy and Lebouteiller

1998); Antiochia/Psidia (Burdy and Taşlalan 1997); Keramos (Bildirici 2006; D.S.İ. 2008); Ilion (Kayan 2000; Aylward et al. 2002; Aylward 2006); Ariassos (Owens 2006); Rhodiapolis (Murphy 2006); Sagalassos (Martens 2006); Sbede (Bildirici 2014).

Furthermore, some water conveyances in Turkey's mediterranean region, like Phaselis, Selge, and in Western Anatolia, like Aigai, Sebastopolis, Pınara, Attuda, Trapezopolis, Nysa, Knidos, Arykanda, Eumenia, Mylasa (with an apparently 2.3 km long, damaged aqueduct) were investigated at national context (Büyükyıldırım 1994; D.S.İ. 2008).

Water distribution and wastewater collection systems of certain hellenistic-roman-byzantine cities in Anatolia deserve also special attention, such as Priene, Miletus, Ephesus, Hierapolis, İstanbul (Bildirici 2002; Crouch 2004; Ortloff and Crouch 1998, 2001; Wiplinger 2006b; Tuttahs 1998; I.W.A. 2012; Strobel 2013; Uytterhoeven 2013).

Covered and open cisterns in İstanbul, dating back to 4th to 6th centuries AD, are extraordinary examples of antique cisterns. They were the largest of their kinds, with side lengths up to 150–250 m. Noteworthy are the covered cisterns Yerebatan with 336, Binbirdirek with 234 columns (Eyice 1979; Öziş 1982; I.W.A. 2012).

There are also other sites with important cisterns, like Termessos (I.W.A. 2012), Rhodiapolis (Murphy 2006); Sagalassos (Martens 2006).

4.2 Structures Covering Water Courses

The tunnel-like twin structures from the Roman period, covering the Bergama creek, date back to early 2nd century AD; they were the largest of their kind with 7.5 m height and 9 m width each; they have a capacity of 720 m³/s and are still in situ.

There exist also two less large structures, the one in Nysa with dimensions close to 6 m and a capacity of 290 m³/s, that in Acarlar near Ephesus with dimensions of 3.3–4.9 m and a capacity of 70 m³/s (Öziş et al. 1979b, 2010; Grewe et al. 1994; D.S.İ. 2008; Baykan et al. 2011).

4.3 Tunnels

The tunnel and river diversion system at Çevlik dates back to the Roman period. The construction began in 1st and ended in 2nd century AD. It was aimed to prevent the silting of the harbor of Seleucia Pieria near Antakya.

The 875 m long system has a capacity of 70 m³/s. It encompasses two tunnel stretches of 90 and 30 m in length. The cross sections are of simple horseshoe or trapezoidal, with dimensions in the order of 6–7 m; and was the largest of its time (Alkan and Öziş 1991, 2013; Garbrecht 1991b; Grewe 1998, 2010; D.S.İ. 2008; Grewe et al. 2010; Öziş et al. 2010; Baykan et al. 2011).

The 250 m long Bezirgan tunnel near Kalkan, with 1.1 m width and 2.2 m height, serves as flood water emissary of the karst polje (Genç et al. 2010; Öziş et al. 2010; Baykan et al. 2011).

There are some water channels, dating back to 4th-3rd centuries BC, at the Amasya castle, located on the mountain overlooking the city (D.S.İ. 2008).

4.4 Dams

Several dams in Central Anatolia, dating back to the early centuries of the 1st millenium AD, like the 16 m high Örukaya, 16 m high Çevlik, 10 m high Çavdarhisar, 4 m high Böğet, others

dating back to the 6th century AD, like the Dara dams near Mardin in South-eastern Anatolia, are interesting remains from this period. The Ildır dam near Çeşme, the Löstüğün dam near Amasya date probably back to the second half of the 1st millenium AD. Sultan and Sihke dams near Van, with some Urartu origins, might also date from the same period (Schnitter 1979; Garbrecht 1991c; Öziş 1999).

4.5 Water Power

There are numerous remains of water mills in Turkey; it is hard to conclude that some of them date back to this period. It is believed, however, that the first water wheel has been constructed in 4th century BC in Cabeira (Niksar) in Turkey (I.W.A. 2012).

Remains of roman water-powered stone saws were found at some locations in Anatolia (Seigne and Morin 2006; Grewe and Kessener 2007).

5 Seljukide Water Works

5.1 Dams

Certain dams in Turkey date back to 11th to 14th centuries, the Seljukide period in Central and Eastern Anatolia. The remains of some dams have been submerged in the reservoirs of modern dams like Altınapa and Sille, others damaged by outside effects.

The most interesting example is probably the 12 m high Faruk dam near Van, with a crest length of 30 m, before the left half collapsed in 1988. The estimates for the construction date of the Faruk dam varies from the Urartu to Ottoman periods, but the appropriate dating appears to be Seljukide (Schnitter 1979; Çeçen 1987; Garbrecht 1991d; Öziş 1999; Bildirici 2004; Öziş et al. 2007).

5.2 Irrigation

The Sahip Ata irrigation canals in Konya date back to the 13th century. The irrigation systems in Ereğli and at other places in Central Anatolia, some of them with probable Hittite origins, date also back to the Seljukide period; a few of them are still in operation (Bildirici and Bildirici 1996; Bildirici 2004). Some underground conduit systems might date back to this period (I.W.A. 2012).

5.3 Water Power

The supply canal of a water-mill at Çermik passes through an asymmetrical opening of the Seljukide Haburman masonry bridge from 12th century (Fig. 5). This is apparently one of the most ancient water power schemes in Anatolia, being still in operation (Öziş et al. 2007).

5.4 Hydromechanics

The book by Ebul-feyz El Cezeri, who was named after the town Cizre in South-eastern Anatolia, is a 12th century masterwork on ingenious hydro-mechanical devices (Cezeri 1196; Hill 1974; Çeçen 1979a; I.W.A. 2012).



Fig. 5 Watermill supply canal through the Seljukide Haburman bridge in Çermik (photo:Ü.Öziş)

6 Ottoman Water Works

6.1 Water Supply and Conveyance Schemes

The Halkalı water conveyance systems to İstanbul were constructed in the period of 1450's to 1750's. They consist of 16 systems with a total length of 130 km, including the 50 km long Süleymaniye water conveyance by the great engineer and architect Sinan in 1550's. The conduits are basically baked clay pipes, with certain tunnel sections and passing over some aqueducts; the Süleymaniye system made even use of the 4th century Mazul and Bozdoğan aqueducts (Çeçen 1979b, 1988, 1990, 1991a; Öziş 1984, 2001; Öziş and Arısoy 1987, 1996, 2000, 2003; Öziş et al. 2007; Acar 2010; I.W.A. 2012).

The 50 km long Taşlımüsellim water conveyance system to Edirne, is also considered as a work of Sinan, dating back to 1530's and expanded some decades later. The conduit is a masonry gallery; the alignment passes over several aqueducts and includes certain tunnel sections; the system is for the large part still in operation (Öziş and Arısoy 1986, 1987, 1988, 1996, 2000, 2003; Öziş et al. 2007; D.S.İ. 2008).

The 55 km long Kırkçeşme water conveyance system to İstanbul from 1560's, is one of the masterworks of Sinan, with four major aqueducts (Uzun, Eğri, Mağlova, Güzelce). The system includes more than thirty aqueducts of various sizes. The conduit is a masonry gallery, and is for the large part still in operation (Çeçen 1979b, 1988, 1990; Öziş 1984, 1987, 2001; Schnitter 1990; Öziş and Arısoy 1987, 1996, 2000, 2003; Öziş et al. 2007; D.S.İ. 2008; I.W.A. 2012).

Sinan's schemes are the most important long-distance water conveyance systems since Roman times. The aqueducts Uzun, Eğri, Mağlova (Fig. 6), Güzelce of the Kırkçeşme system, with heights up to 35 m and lengths up to 700 m, rank among the largest of their kinds in all times.

The Üsküdar water conveyance systems, to the east of Bosphorus in İstanbul, date back to 16th to 19th centuries. The conduits are mostly baked clay pipes; noteworthy are the water balance towers for pressure control and distribution (Çeçen 1979b, 1991b; Öziş et al. 2007; Dinçkal 2001; I.W.A. 2012).

The 23 km long Taksim water conveyance to İstanbul dates back to 1730's, and is still for the large part in operation. The conduit is a masonry gallery; it includes a 400 m long aqueduct and initially an interesting inverted siphon. Collecting water from the same area, a new system



Fig. 6 Mağlova aqueduct on the Kırkçeşme water conveyance system to the Ottoman capital İstanbul (photo: Ü.Öziş)

for drinking water purpose, the Hamidiye water conveyance, has been constructed in the 19th century (Çeçen 1979b, 1992; Öziş 2001; Öziş et al. 2007; I.W.A. 2012).

The short Kilyos water conveyance near İstanbul, is interesting with regard to the water balance towers (Bildirici 2008).

The diversion and conveyance of Ephesus' Değirmendere waters to Kuşadası, the water conveyance with aqueducts to Foça date back to ottoman times; some of the ottoman water conveyances to İzmir (Öziş et al. 1999; D.S.İ. 2008), the Paşasuyu water conveyance to İzmit (Ünal 2001) have roots in ancient periods.

The water supply systems of Şanlıurfa, having roots in the Seljukide period (Gerger and Kürkçüoğlu 1997; I.W.A. 2012); of Bursa (I.W.A. 2012), of Çorum (I.W.A. 2012), of Safranbolu (I.W.A. 2012) are other interesting systems.

Besides the water conveyances, the water distribution and wastewater collection systems of İstanbul deserve also special interest (Sarıkaya et al. 2001; Bildirici 2002; Dinçkal 2005; I.W.A. 2012).

The cisterns, especially in western and southern regions of Turkey, are quite interesting (I.W.A. 2012).

6.2 Dams

In the period of 1620 to 1839, the Kırkçeşme system is supplemented by four (Topuz, Büyük, Ayvat, Kirazlı), the Taksim system by three (Topuzlu, Valide, Yeni) dams, with heights up to 17 m and crest lengths up to 104 m. All these dams, located at the Belgrad Forest to the north of İstanbul, are still in operation (Öziş 1977, 1981, 1984, 1999; Çeçen 1979b, 1987, 1988, 1990; Schnitter 1994; Öziş et al. 2007; D.S.İ. 2008; Acar 2010).

The majority of dams constructed until these centuries were embankment dams, and masonry dams were rarely encountered; thus, the masonry dams of İstanbul deserve a special place with regard to the historical development of dams.

There are also some later dams of 19th century like Şamlar and Elmalı I dams around İstanbul (Çeçen 1987; Öziş 1999), the 23 m high Maden dam near Karasu. The Semalı embankment dam near Amasya, mentioned in certain sources that the imperviousness was achieved by covering the upstream face with ox-skins, is considered as an Ottoman dam (Öziş 1999).

6.3 River Diversion

The engineer and architect Sinan planned in 1583 the diversion of the Sakarya River to the Marmara Sea over the Lake Sapanca, for flood control, water power (mills), river navigation purposes. This idea had roots in 16th century, but could not be yet realized until present times (Çeçen 1981).

The Gediz River was diverted to the outer bay in late 19th century, in order to prevent the closure of the İzmir Bay (Öziş 1994).

6.4 Irrigation

Various irrigation systems under actual operation have their roots in ottoman times, like the Sürgü irrigation near Malatya from 19th century, the Beyşehir-Çumra irrigation south of Konya from early 20th century (Öziş 1994; Öziş et al. 2009).

6.5 Water Power

The first electricity was generated in Turkey in 1902 at the Tarsus hydroelectric scheme, at the dawn of the Ottoman Empire (Öziş 1994; Öziş et al. 2009, 2014b). The scheme used the elevation difference of the Berdan River at Tarsus falls.

7 Conclusion

Ancient hydraulic works, dating from all periods of her last 4000 year long history, make Turkey one of the foremost open-air museums in this respect. Some of them are, with very few repairs or modification, still in operation after several centuries, even millenia.

Based on this tradition, Turkey continues to harness her water resources, including very important schemes like the Southeastern Anatolia Project, the Karakaya and Atatürk dams and power plants, the twin Şanlıurfa tunnels. Turkey anticipates the development of the bulk of her water resources until 2023, the centennial of the foundation of the modern Republic of Turkey.

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