Roman Water Systems In South-Central Turkey

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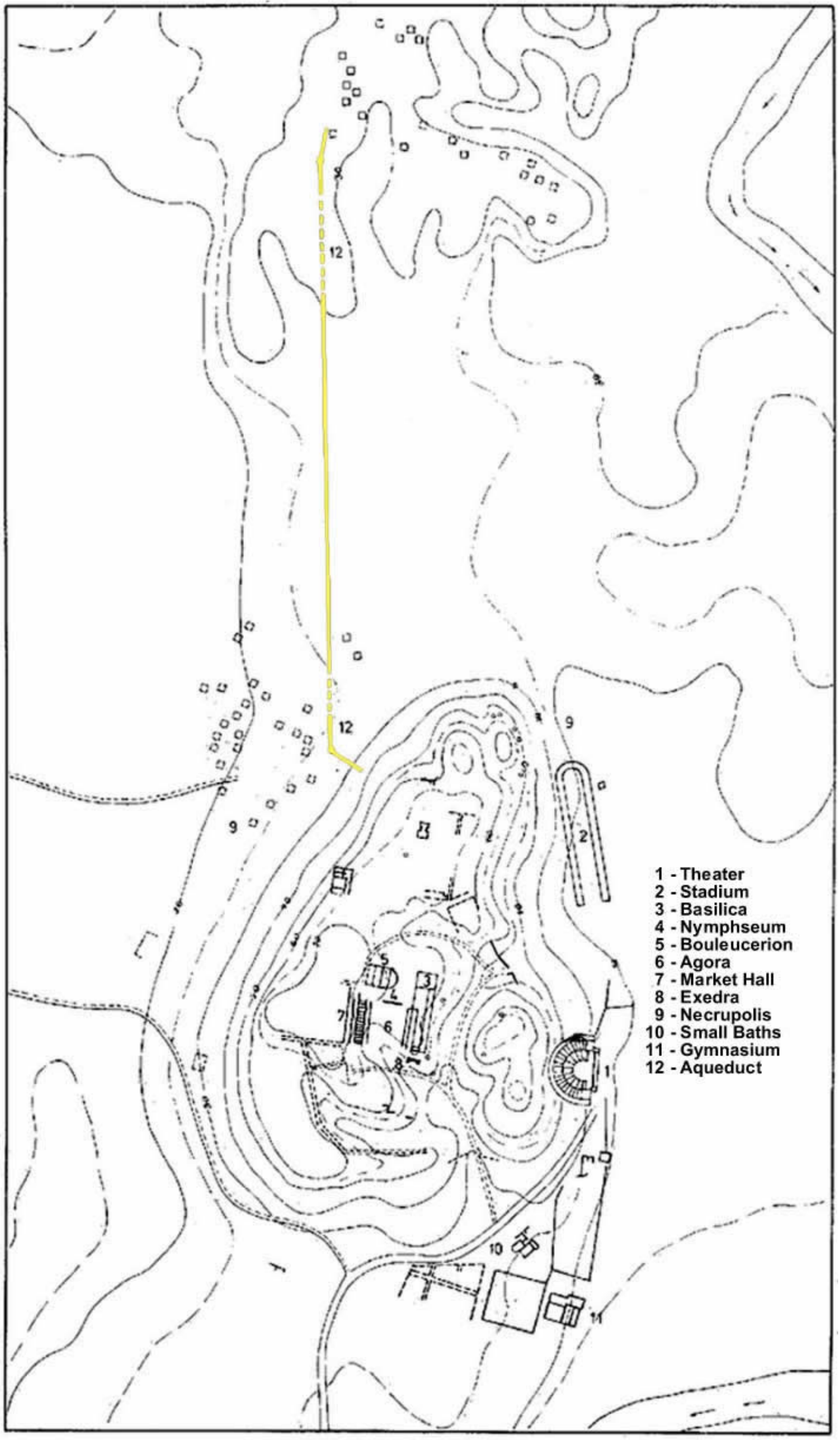
Ruins and archaeological evidence in southern Turkey graphically illustrate several key points relating to Roman water systems. Aspendos had three consecutive inverted siphons integrated into its impressive aqueduct system, demonstrating a sophisticated knowledge of hydraulic engineering. Perge illustrates the Empire's remarkable dependence on high-quality water.

ASPENDOS

To understand the complexity of some of the Roman era aqueducts, a visit to Aspendos is useful. Aspendos is located 45 kilometers east of modern-day Antalya, in south-central Turkey. Aspendos is best known for its well-preserved Roman theater. Built in the second century and seating 15,000, the structure is nearly intact.

Aspendos had its golden age in the 2nd and 3rd century A.D., when it was an important port and overland trade center. In ancient times, the Eurymedon River, which flows into the nearby Mediterranean Sea, was navigable as far as the city. Like other cities in antiquity, Aspendos was constructed on a hill (for a map of ancient Aspendos see illustration 1); defense was an important consideration in the city's development. Early water needs were met by cisterns which collected rainwater, and by local springs. In time, however, as the population grew and the standard of living rose, water needs got to point where an aqueduct was needed. And the aqueduct had to bring water across an adjacent valley to the top of the acropolis.

My two sons and I visited Aspendos in June, 1989. Arriving at the ancient city, we first visited the theater (see illustration 2) and then walked up to the ruins on the acropolis. I was surprised when I saw the remains of the ancient aqueduct (see illustration 3 and photograph 1). It is one of the most impressive water conveyance structures remaining from the Roman era.



Plan of Aspendos

Illustration 1. Plan of Aspendos.

Photograph 1. From the ancient site of Aspendos, the traveler gets an impressive view of the remains of the ancient Roman aqueduct.

Illustration 2. Roman theater in Aspendos (circa 1890).

Illustration 3. Remains of the Roman aqueduct at Aspendos (circa 1890).

Water from two sources, located in the mountains 17 kilometers to the north, was carried to within 2 kilometers of the city in a conventional aqueduct channel. The aqueduct is thought to have been constructed in the first half of the 2nd century. It incorporated several bridges and tunnels, the channel having modest dimensions, 55-60 cm wide and 90 cm deep on the inside. The last 1.7 kilometers, between the foothills to the immediate north and the acropolis was a complex combination of elevated sections and inverted siphons. The most eye-catching structures are two massive water towers.

From the acropolis, across a small valley or depression, is the first tower (farthest away). This two-tiered structure bends slightly in the middle to form a 175 degree angle. It is assumed that the top of the tower was equipped with an open tank. The arches of the tower slope down on both sides, indicating that the tower held a receiving tank for the first inverted siphon and the header for the second. (The hydraulic structure is called an inverted siphon because the water follows the path of a "U" rather than the initially upward course (resembling an "n") of a true siphon.

The second siphon, which connects the two towers and stretches over 900 meters on a straight line, is carried on a row of arches (also called a venter) 15 meters high (see photograph 2). The purpose of the venter was to reduce the head, or the drop from the header tank to the bottom of the inverted siphon. This section of the aqueduct was 5.5 meters wide leading some to speculate that it was also used as a roadway when the ground in the valley became marshy.

After crossing the valley, water flowed up to the second tower, which bends to form a 125 degree angle (see photograph 3). This tower constitutes the transition between the second and third siphon. It also probably had a tank at the top. From the second tower, water was conveyed a short distance to the city by a third inverted siphon, again carried on arches. Each tank on the Aspendos/inverted-siphon system was a little lower than the preceding tank because friction in the pipes slowed the water, the difference in elevation is the hydraulic gradient.

Photograph 2. To get across a valley, the Aspendos aqueduct used an inverted siphon carried on arches (venter). In the distance is the second tower.

Photograph 3. The second tower for the Aspendos aqueduct has a 125 degree bend.

Today the two towers stand 30 meters above ground level. But during archaeological investigations in 1996, when the siphons were traced from header tank to receiving tank, it was deduced that the towers were originally approximately 40 meters high. This would make the Aspendos towers among the highest of Roman constructions. By comparison, the aqueduct bridge at Pont du Gard is 48.77 meters in height.

It has been hypothesized that for a valley or canyon crossing under 50 meters deep, Roman engineers used a bridge alone (Smith, 1978, p. 156; Hodge, 1985, p. 119). For crossings over 50 meters deep, an inverted siphon was the choice. The depth of crossing at Aspendos is approximately 55 meters (the towers were 40 meters, plus the venter was 15 meters), just over the hypothesized 50-meter cutoff.

There is a question of how Roman engineers designed and constructed inverted siphons. Smith (1978, p. 157) postulates that "the required design was arrived at empirically." The engineer would build the header tank and pipes first and then would "resort to judicious trial and error to finally position the receiving tank." For me, this does not seem very plausible for the structure at Aspendos, one with multiple siphons in series.

The pipes for the inverted siphon where made of stone. The inside circular diameter was 28-30 centimeters, and the outside was a 86x86x50-90x90x70 centimeter block (see illustration 4). The pipe elements were joined together by means of a socket and flange system and sealed off by a mixture of lime and olive oil. This latter concoction expands and hardens when in contact with water and can withstand considerable water pressure. One can still see a few of the stone-pipe blocks lying along the course of the aqueduct. Originally the three inverted-siphon sections contained over 3,000 stone-pipe blocks.

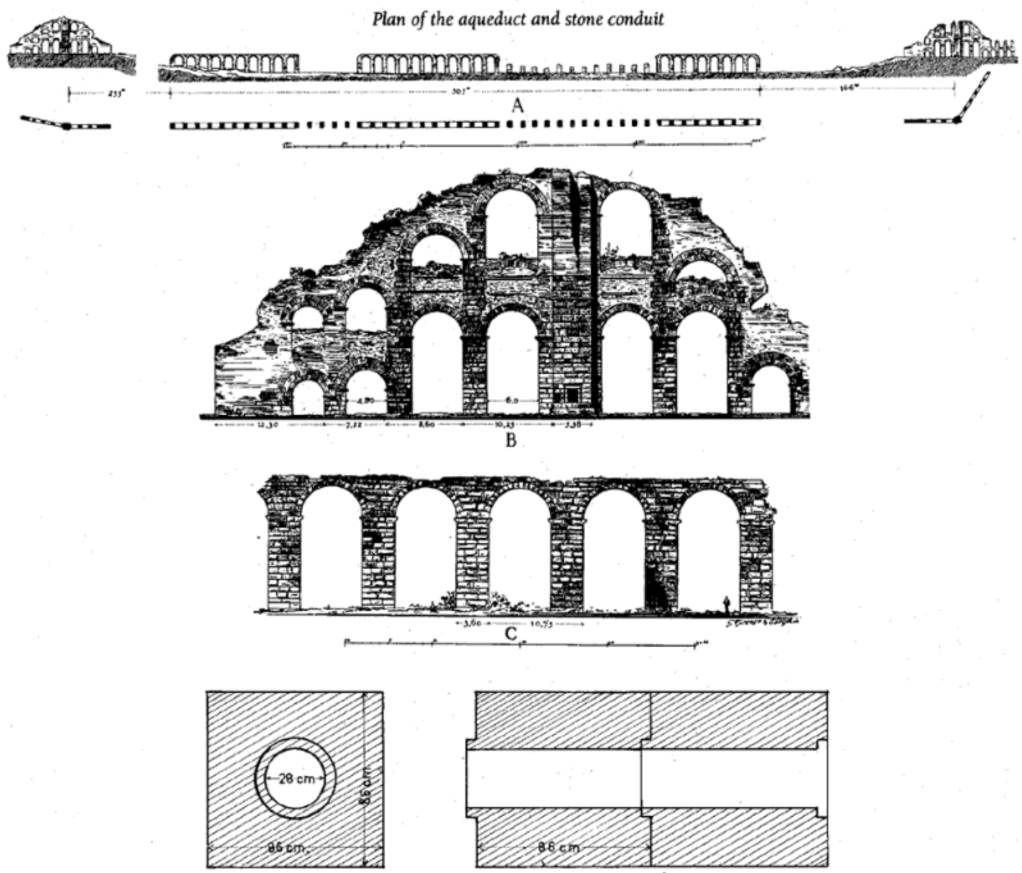


Illustration 4. General layout and dimensions of the Aspendos aqueduct.

Once the water arrived at the edge of the acropolis, it was carried by means of an open channel toward the richly decorated *Nymphaeum*, which stands today on the north side of the agora. From the *Nymphaeum*, where the citizens drew water from basins along its front, the water presumably flowed to the huge cistern on the east side of the agora, and also to both bath complexes, which are down on the plain to the south of the acropolis.

It has been long known that stone-block pipes from the Aspendos siphons were used in the construction of a Seljuk-era road bridge over the nearby Eurymedon River. But surprisingly, during recent archaeological investigations, it was determined that siphon spolia was used in a Roman predecessor to the Seljuk bridge. As the inside perforations of several of the block pipe used in the bridge had calcareous incrustations, these stone-block pipes had definitely been used in the aqueduct. Thus the Romans reconstructed their road bridge after the Aspendos aqueduct had been abandoned.

From the thickness of the calcareous deposits (sinter) in the aqueduct channel found 10 kilometers north of Aspendos, it was estimated that water flowed in channel for about 130-150 years. Kessenner and Piras (1998) speculate that the Aspendos siphon may have been destroyed by an earthquake, like the one that occurred in Cyprus (located 250 kilometers southeast) in 363 AD. Such an earthquake could well have destroyed the aqueduct including the siphon and its elevated towers, while also ravaging the road bridge over the Eurymedon. The bridge was important for the east-west trade route along the coast; it was the only place to cross the fast flowing river. As the Aspendians did not want to lose their trading position, their most pressing interest was to rebuild the bridge, and the spolia from the aqueduct was certainly convenient.

If we assume the construction date of the aqueduct to be in the first half of the 2nd century AD, after which the aqueduct functioned for about 150 years, it seems probable that the Roman bridge was reconstructed sometime in the early 4th century AD. Later this bridge was again destroyed, but it served as the foundation for the Seljuk bridge constructed about 900 years later.

PERGE

To understand the Roman Empire's reliance on water, a visit to nearby Perge is particularly instructive. The ruins of Perge are located 20 kilometers east of the modern city of Antalya. My sons and I also visited Perge in 1989 and were surprised by what the archaeological evidence indicates about the Roman use of high-quality water (for a map of Perge see illustration 5).

At the southern edge of Perge's acropolis was a monumental fountain (see illustration 6). It is located at the end of a colonnaded street. The fountain was discovered during excavations in 1970. Water was delivered to a pool located behind the facade via a covered canal. From this pool water flowed through an opening just below a reclining statue of Cestrus (river god) and into an exposed, decorative pool (see photograph 4). From here water overflowed into a canal which divided a colonnaded street.

The city of Perge was surrounded by a wall. And was divided into 4 sections by two intersecting colonnaded streets. The street running north and south had a 2-meter-wide canal running down its center. The canal had check structures every 7 to 8 meters to pool the water and facilitate cleaning (see photograph 5). There were walkways over canal. The sound of water falling over the barriers must have produced a soothing effect during the hot summers.

Located at the southern end of the colonnaded street was an agora. It was commercial, social, and political center of the city. The agora was a square surrounded by shops, some opening inward and some outward to the street. At the center of the agora was a circular water reservoir and fountain. In the southeast corner of the agora was a latrine. Water ran through the latrine in a continuous flow. It was connected to Perge's main drainage canal.

Also at the southern end of the colonnaded street was a large bath. Since most residential units had no bathing facilities, every Roman city had public baths. Perge's Southern Bath had hot and cold water and separate bathing areas differentiated by water temperature (see photograph 6). An underground network of pipes supplied the bath with clean water.

Photograph 4. This two-story monumental fountain, located in the ancient city of Perge, provided water to a canal which ran down a colonnaded street.

Photograph 5. This section of Perge's colonnaded street had a canal running down its center

Photograph 6. In this pool at the Southern Bath, Romans bathed in hot water. Note the underground central heating system.

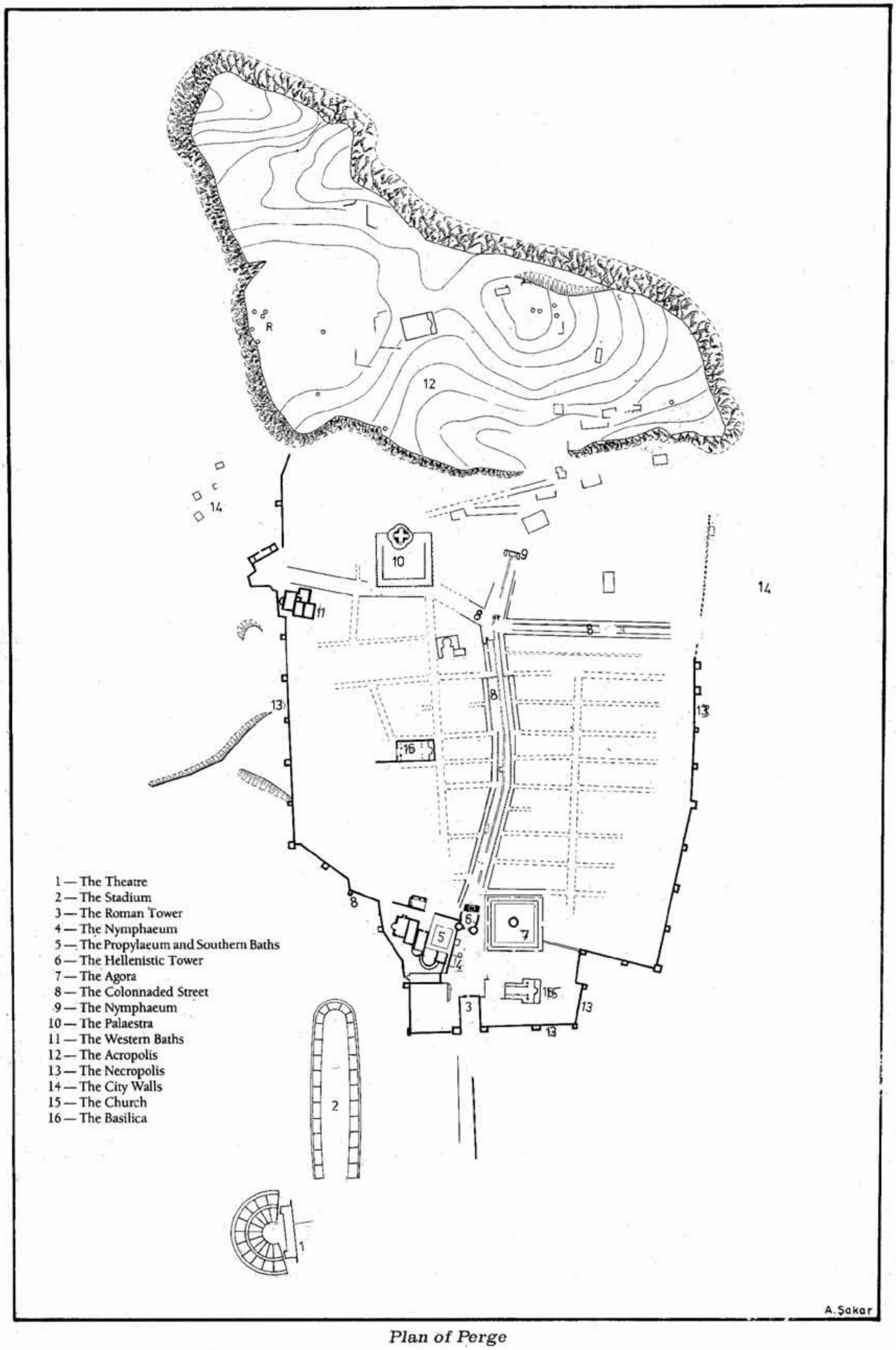
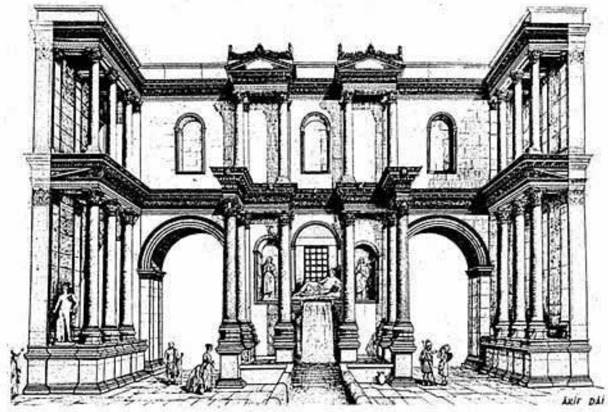


Illustration 5. Plan of Perge.



Reconstruction of the nymphaeum

Illustration 6. Reconstruction of Perge's two-story monumental fountain.

CONCLUSIONS

No matter how close to the next city or how far from the Roman capital, every town in the Empire was entitled to a full infrastructure: the protective wall, the paved streets, the gurgling fountains, the monumental baths, and the majestic aqueducts.

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[*]Illustrations 2 and 3 courtesy of Suna & Inan KIRAC Research Institute on Mediterranean Civilizations