2012, Scienceline Publication

Journal of Civil Engineering and Urbanism

Volume 3, Issue 1: 01-05 (2013) (Received: March 13, 2012; Accepted: August 16, 2012; Published: January 30, 2013) **ISSN-2252-0430**

Ancient Tunnel and Diversion Channel in Seleuceia Pieria: A Flood Diversion System near Antiochia in Turkey

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ABSTRACT: The diversion system at Çevlik, near Antakya in Turkey, had the purpose to prevent the siltation of the antique harbour of Seleuceia Pieria. This 875 m long system consists of a dam, a short approach channel, the first tunnel, a short intermediary channel, the second tunnel, a long discharge channel. The construction began in 1.century A.D. during the reign of Vespasianus, continued under his son Titus and several successors, completed in 2.century A.D. during the reign of another roman emperor, Antonius Pius. The tunnels of simple horseshoe and trapezoidal cross-sections, with dimensions in the order of 5 to 7 m, have a capacity of 150 m^3/s. The capacity of the open channel section is computed as 70 m^3/s, corresponding to a peak flood discharge with average recurrence interval of about 10 years.

Keywords: Çevlik, Seleuceia, Tunnel, Flood, Diversion.

ORIGINAL ARTICLE

INTRODUCTION

Anatolia was at the crossroads of several civilizations during the last 4000 years, where a great variety of hydraulic structures were implemented, making Turkey one of the foremost open-air museums of the world in this respect (Öziş 1994, 1996, 1998, 1999, 2006; Öziş, Baykan et al. 2006).

Magnificent examples of tunnels as part of long-distance water conveyance systems, with heights of around 2 m and widths less than 1 m, are encountered especially in systems supplying water to ancient cities. Among these systems in Turkey, special interest deserve those of İstanbul, Pergamon, Ephesus, Side, Elaiussa Sebaste, Olba, Diocaesarea, Phocea, Samosata.

Outside of Turkey, besides the famous Hezekiah tunnel in Jerusalem and the Eupalinos tunnel in Samos)Kienast 1984; Grewe 1998), tunnels in water conveyance systems of Bologna (Giorgetti, 1988), Lyon (Burdy 2002), Nîmes (Fabre, Fiches et al. 1991) are of great interest.

Underground conduits called qanats in eastern Turkey and especially in Iran, dating back to the I.millenium B.C., tunnels of etruscan origin to drain some closed basins in Italy, deserve also special attention (Grewe 1998).

Tunnels of greater dimensions with large capacities, conveying a significant part of the discharge of a watercourse, like the ones in Seleuceia Pieria in Turkey, Petra in Jordan, Montefurado in Spain, are quite rarities. Seleuceia Pieria has heights and widths in the order of 5 to 7 m (Aygen 1985; Garbrecht 1990, 1991, 1995; Alkan & Öziş 1991a,b; Grewe 1998), Petra a width of 4.8 m and height up to 8.0 m (Lindner 1987; Grewe 1998).

They can only be matched by tunnel-like superstructures covering the entire watercourse; like those in Pergamon, with two adjacent conduits of 7.5 m height and 9 m width each, Nysa with heights and widths of about 5 to 7 m, Ephesus with smaller dimensions (Öziş, Harmancıoğlu et al. 1979; Grewe, Öziş et al. 1994).

Location

The antique city Seleuceia Pieria is situated near the actual village Çevlik, 35 km to the southwest of Antakya (the historical city Antiochia ad Orontes), at the foot of Nur mountains in eastern mediterranean coast in Turkey (Figure1).

Seleuceia Pieria was founded towards the end of the 4.century B.C. by Seleukos Nikator I, one of the generals of Alexander the Great. The city was reigned by the Ptolemeans during the second half of the 3.century B.C., and flourished later during the Roman period, beginning in the second half of the 1.century A.D., and became one of the most important ports of the eastern mediterranean region (Cimok 1980; Pamir 2004).

The upper city is separated from the lower one by steep rocky topography. The lower city, surrounded by fortification walls totalling 12 km, has been developed around the harbour of 16 hectares area.

The city declined after the earthquakes in the first half of the 6.century; and the harbour is later completely filled with sediments, as it can be seen actually.

The diversion system

The system to divert the creek flowing originally at the site of the port to the Mediterranean Sea, had the purpose to prevent the siltation of this very important harbour. It is located to the northwest of the lower city. The general layout of the system is given in Figure1; the cross-sections at various points are given in Figure2.

The construction began in 1. century A.D. during the reign of the roman emperor Vespasianus (69-79 A.D.), continued under his son Titus (79-81 A.D.) and his successors, completed in 2.century A.D. during the reign

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Journal homepage: http://www.ojceu.ir/main/

of another roman emperor, Antonius Pius. A rock-carved inscription at the entrance of the first tunnel section bears the names Vespasianus and Titus, another inscription in the downstream channel that of Antonius.

The diversion system, displaying a broken alignment, consists of: (a) a dam to divert the river flow; (b) a short approach channel; (c) the first tunnel section; (d) a short intermediary channel; (e) the second tunnel section; (f) a long discharge channel.

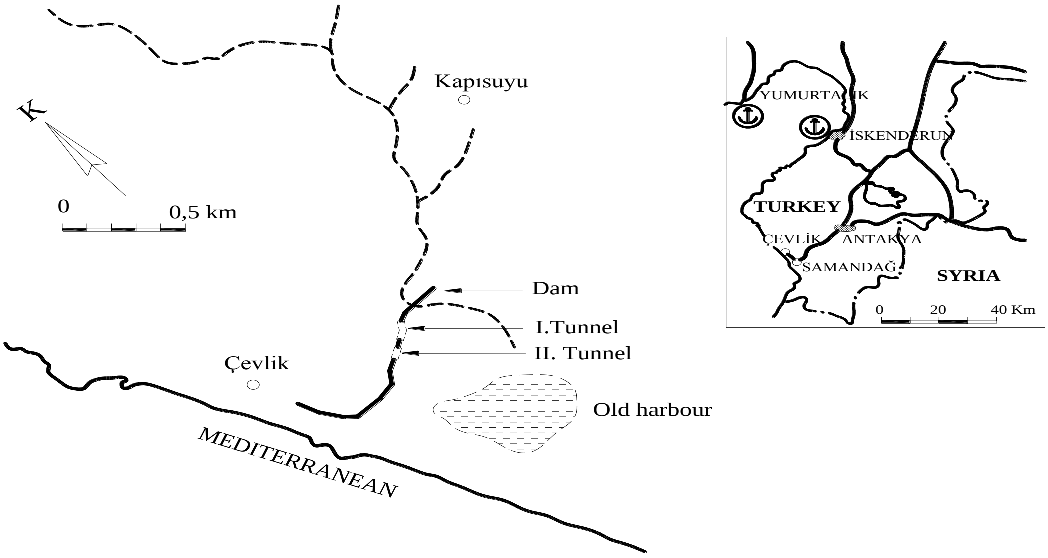

Figure1. Location of the ancient tunnel and channel diversion system of Seleuceia Pieria [Alkan and Öziş, 1991 a]

Dam

The dam to divert the creek flowing into the harbour is a masonry structure of 16 m height, 5 m crest width and 49 m crest length; rising to elevation 44,30 m above sea level. The damming is completed by a shallow embankment of 126 m length towards the upstream direction.

Approach channel

The diversion begins with a 55 m long approach channel, converging to the entrance of the first tunnel section. This is a rectangular open channel, excavated in the karstified limestone formation.

First tunnel section

The first tunnel section, designated as tunnel I, has a simple horseshoe cross-section of 6.3 m width and 5.8 m height at the entrance (Figure3), being 90 m long. The cross-section changes to an almost rectangular shape three meters after the entrance; and is 6.9 m wide and 6.5 m high at the outlet.

Intermediate channel

The width of the open channel between the first and second tunnel sections decreases to 5.5 m. The height of this 64 m long channel reaches up to 25-30 m and becomes narrower close to the surface, because of former karst solution channels encountered along its alignment.

Second tunnel section

The second tunnel section, designated as tunnel II, is 31 m long. Its entrance has a rectangular cross-section with 7.3 m width and 7.2 m height; the outlet is trapezoidal with 5.5 m base width and 7.0 m height (Figure4). The total length of the two tunnel sections amounts to 121 m.

There is a small rock-cut springwater conveyance channel of 0.4 m width and 0.3 m height on the left wall of the tunnels.

Shortly after the outlet of the second tunnel section, there exists an arch of a bridge, or rather an aqueduct, of 4.5 m height and 5.5 m span width, crossing the channel.

Discharge channel

The open channel serving as the main discharge conduit, following the outlet of the second tunnel section, displays rectangular cross-sections excavated in karstified limestone formations. The widths vary from 3.8 to 7.2 m, the heights from 3.7 to 15 m.

The discharge channel is 635 m long; so that the total length of the diversion system is around 875 m.

Hydraulic capacity of the system

The hydraulic capacity of the diversion system is computed as about 70 m^3/s, based on determination of water surface levels through step-by-step integration (Figure5). The hydraulic capacity of the tunnel sections is almost twice of the system, about 150 m^3/s.

Four synthetic unit hydrograph methods were applied to estimate the anticipated flood discharges from the 13 km^2 drainage area. Besides the universally known Snyder and Mockus methods, the D.S.I. method, developed for Turkey by the State Hydraulic Works Authority, and the Günerman method developed especially for the aegean region of Turkey, have been applied.

The results were somewhat different especially the Snyder method yielded highly different results. The Günerman method yielded the highest flood peaks, followed by Mockus and D.S.I. methods, whereas the Snyder method resulted in the lowest flood peak series.

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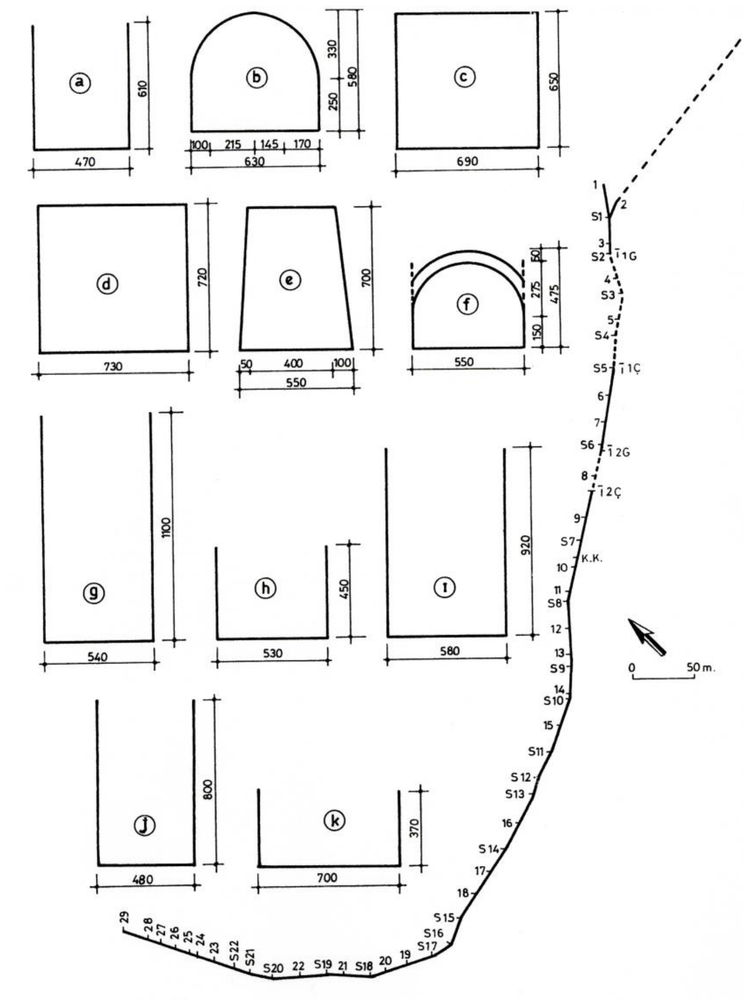

Figure 2. Layout and typical cross-section of the Seleuceia Pieria canal and tunnels (Alkan &Öziş 1991a, b): (a) at S1, the beginning of the approach channel; (b) at TIG, the entrance of the first tunnel; (c) at TIÇ, the outlet of the first tunnel ; (d) at T2G, the entrance to the second tunnel ; (e) at T2Ç, the outlet of the second tunnel; (f) at K.K, the site of the arch; (g) at S11; (h) at S14; (i) at S18; (j) at S21; (k) at S22, all along the discharge channel (Alkan & Öziş 1991 a, b).

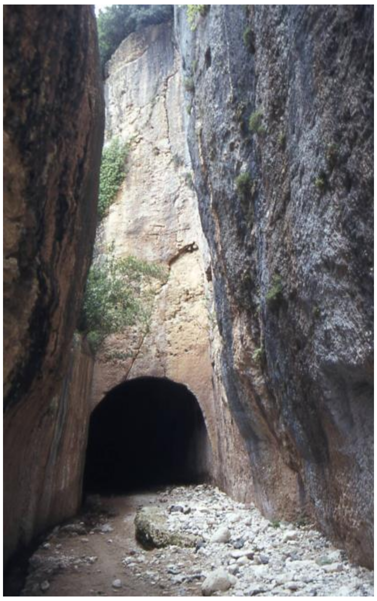

Figure 3. Entrance to the upstream first tunnel, with 5.8 m height and 6.3 m width, in Seleuceia Pieria (photo: Ü. Öziş).

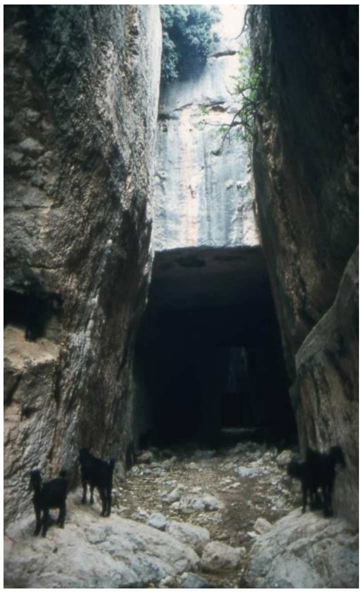

Figure 4. Outlet of the downstream second tunnel, with 7.0 m height and 5.5 m base width, in Seleuceia Pieria (photo: Ü. Öziş).

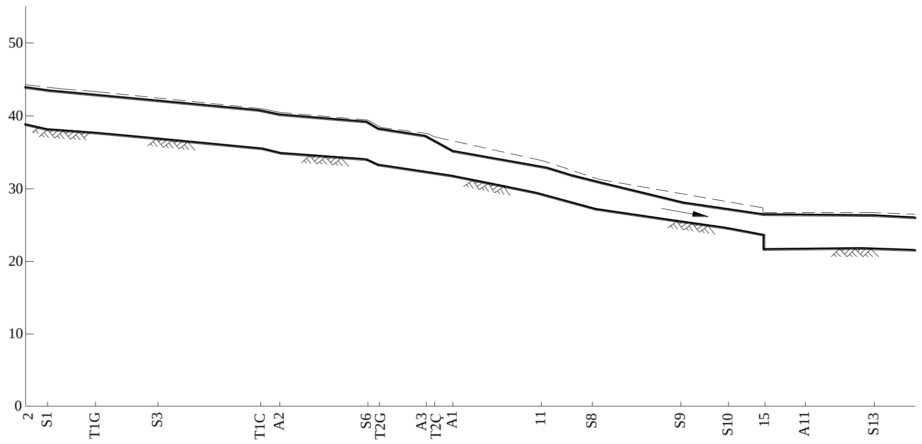

Figure 5. Longitudinal section of the 875 m long tunnel and channel system of Seleuceia Pieria (Alkan & Öziş 1991, a).

The effective precipitation over the drainage area of the diversion dam was computed by the iso-deviation method, developed by Saydam in Turkey, based on gagings at 15 meteorological stations in the surrounding area, for various recurrence intervals. The frequency distribution of flood peaks suited preferably Gumbel distribution for Mockus and D.S.I. methods, log-Gumbel distribution for Günerman and Snyder methods, lognormal distribution for the mean values of the four methods, being also the case for the distribution of effective precipitation estimates.

The comparison of these flood peak discharges with the 70 m^3/s capacity of the diversion system, showed that it correspondeded to a peak flood discharge with average recurrence interval in the order of 10 years, in the case of the Snyder method even 100 years (Alkan & Öziş 1991 a, b).

The tunnel capacity of 150 m^3/s corresponded to a peak flood discharge with average recurrence interval of about 200 years, being larger than 1000 years for the Snyder method.

CONCLUSION

The tunnel and open channel system in Seleuceia Pieria, for diverting the discharges of the creek in order to prevent the siltation of the harbour, is an outstanding example of hydraulic structures in antiquity, not only in Turkey (Öziş 1994, 1996, 1998, 1999, 2006; Öziş, Baykan et al. 2006), but also in the world (Schnitter 1994; Garbrecht 1995; Grewe 1998) (an interior view of the Çevlik tunnel covers the front page of Grewe's distinguished book).

The system of about 70 m^3/s capacity, dates back to the 1.-2.centuries A.D., with tunnel dimensions in the order of 5 to 7 m. The total length of the two tunnels is 120 m, the total length of the system 875 m.

It should be noted that, about 275 km to the north-east of Çevlik, the modern Republic of Turkey has constructed the Şanlıurfa twin-tunnels towards the end of the 20.century. These are actually the longest water tunnels of the world, with 26.4 km length each, to carry 330 m^3/s irrigation water from the reservoir of the gigantic Atatürk dam on Euphrates to the agricultural lands in Southeastern Anatolia (Öziş, Basmacı, Harmancıoğlu 1990, 1992; Kurt 1992).

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