Great Waterworks in Roman Greece

Aqueducts and Monumental Fountain Structures

Function in Context

edited by

Georgia A. Aristodemou and
Theodosios P. Tassios

Archaeopress Roman Archaeology 35

Archaeopress Publishing Ltd
Gordon House
276 Banbury Road
Oxford OX2 7ED

www.archaeopress.com

ISBN 978 1 78491 764 7
ISBN 978 1 78491 765 4 (e-Pdf)

Cover: The monumental arcade bridge of Moria, Lesvos,
courtesy of Dr Yannis Kourtzellis
Creative idea of Tasos Lekkas (Graphics and Web Designer, International Hellenic University)

Printed in England by Oxuniprint, Oxford
This book is available direct from Archaeopress or from our website www.archaeopress.com

Contents

Preface

Georgia A. Aristodemou and Theodosios P. Tassios

The achievements and development of ancient hydraulic engineering that resulted to an efficient use of natural resources and provided ancient civilizations with the means to improve their living standards, attracted the interest of specialists of various disciplines quite early in scholarly research.

Series of international conferences of water management and hydraulic engineering (e.g. the Cura Aquarum International Conferences, Symposia held under the auspices of the Frontinus Gesselschaft, International Water Association Symposia [IWA], and many more) being held the last four decades, have indeed promoted the exchange of scientific knowledge about the latest findings and theoretical approaches and stimulated an interdisciplinary discussion about water management in antiquity, involving Archaeologists, Historians, Hydraulic Engineers, Civil Engineers, Geologists and many other scientists.

Scholarly discussions and relevant publications include (among others) large-scale water transfer structures, such as aqueducts and their complex systems, or monumental fountains, such as nymphaea – and geographically expand throughout the Mediterranean region.

Regarding the Eastern part of the Roman Empire, however, modern research seems to focus more on the Asia Minor, the Levantine and the North African Provinces rather than the Greek provinces.

During the last few years a newly launched discussion on water archaeology in Greece seems to emerge from exactly this need to promote research on this particular field and on this geographical region. However, there is still a definite and considerable gap in modern archaeological research and bibliography, regarding water management and monumental water structures in Roman Greece. The few and scarce publications on aqueducts from the Greek territories usually refer to the technological aspect of these imposing monuments. Though they have increased in number there is still a lack of a concise publication that would provide the archaeological community with gathered knowledge and data upon these significant monuments – on grounds of archaeological information, engineering progress and technological development. Similarly, studies related to monumental fountains and nymphaea in the Greek provinces were until now confined to their architectural and typological study, without expanding to other issues, such as decoration, interaction with their surrounding environment, and their impact upon the local communities.

Based on the above, the collective volume that we here present consists the very first presentation of great waterworks in Roman Greece and aims not only to fill an essential scientific gap but also aims to bring together a wide body of experts along with their knowledge from the newly emerged and expanding field of water technology and water archaeology in Roman Greece. The main goal that this multi-author volume attempts to succeed is to show that large scale waterworks (aqueducts and nymphaea)

- were a striking novelty in the Greek Provinces, both in form and function
- drastically changed the architectural landscape of their surrounding environment
- improved the living standards
- increased the water supply, in quantity and in quality
- introduced the concept of luxury in the urban landscape, and
- formed the link between utility and design, political ambitions and regional development

The invited papers deploy along a wide geographical area, covering the Roman provinces of Macedonia and Thrace, Epirus, Achaia, the Aegean islands and Crete. The chronological frame of the presented subjects extends throughout the Imperial period (1st century BC – 4th century AD).

This multi-author volume is structured in two parts (Part I: Aqueducts; Part II: Monumental Fountains) and evolves around four major axes: Architecture – Engineering – Historical Sources – Decoration.

Within this framework the invited authors addressed issues such as the following:

- Archaeological remains of aqueducts and monumental fountains in Roman Greece
- Technological development of urban water supplies (i.e. castella, aqueducts, fountains, nymphaea, etc) in Roman Greece.
- Function in Context: The interaction and spatial affiliation of aqueducts and nymphaea within the urban environment of Greek provincial cities.
- Sponsors and Benefactors
- Written sources and epigraphical data
- Aesthetics and Sculptural Decoration of Fountains and Nymphaea
- Religious aspects of water use
- Social, Cultural and Political issues of urban water supplies and water consuming structures in the Greek provincial cities.

As editors of this demanding volume, we were glad to invite and honored to welcome a wide range of authors, all expert scientists in the field of Water Archaeology in Roman Greece. Thirteen (13) studies were gathered in the present volume, all presenting us with new and valuable knowledge that addresses the needs of modern scholarship in regards of Roman hydraulic archaeology in Greece.

We are confident that it will soon be a valuable asset for senior and young scholars, as well as for students of a large variety of disciplines, such as Archaeology, History, Architecture, Engineering, Urban planning, etc.

With the increasing worldwide awareness of the importance of water resources management in the ancient civilizations, collective studies such as this, not only will enlighten and project the multifaceted significance of the archaeological remains regarding water management technology of the Roman period in the Greek regions, but they will also reveal the enormous impact of Roman technological heritage in the Greek territories.

As editors of this volume we would like to cordially thank each and every one of our invited authors, for providing us not only with their studies and their expertise, but for contributing to this volume with supreme academic professionalism, consistency and patience.

Furthermore, we extend our appreciation towards Archaeopress and, especially David Davison and Rajka Makjanic, who accepted and undertook the publication of the volume with a genuine academic interest and enthusiasm.

Lastly, we convey our warm thanks to all those people (family, friends and colleagues), who have supported us during the long preparation period of this volume and contributed in many way to its completion.

Dr Georgia A. Aristodemou
Researcher of Roman Archaeology
School of Humanities
International Hellenic University, Thessaloniki, Greece
E-mail: g.aristodemou@ihu.edu.gr;
garistodemou@gmail.com
www.hum.ihu.edu.gr

Dr Theodosios P. Tassios
Civil Engineer
Professor Emeritus, National Technical University,
Athens, Greece
President of the Association of Ancient Greek
Technology Studies
Member of the Academy of Sciences of Turin
E-mail: tassios@ntua.ua

Introduction I.
Roman Aqueducts in Greece

Theodosios P. Tassios

'*Aquae [...] est enim maxime necessaria et ad vitam et ad delectiones, et ad usum cotidianum ...*'
Vitruvius, *De Architectura*, 8.1.1

'*Water is an absolute necessity*
for life, for pleasure and for
daily use...'
Vitruvius, *Of Architecture*, 8.1.1

Preface

Vitruvius, the first Roman technical writer (1st century BC) in his book, *De Architectura* (Chapter VIII) offers several recommendations for the construction of water-supply works. To start with and regarding the methods of catching of waters, he mentions:

(i.) The tapping of aquiferous underground layers by means of several wells, interconnected through subterranean conduits gathering all [waters] into one place (8.1.6).[1]
(ii.) The waters originated from the rain (rivers, mainly, 8.2.6), without any additional technical description.
(iii.) The springs (8.1.6), again without any additional technical description.

Thus, only the underground catching by means of 'wells and fan-of-galleries' is technically described.

As Vitruvius continues (8.6.1-3): 'Water can be conducted in three ways: by flow in masonry channels, lead pipes and terracotta pipes. [...]. If in **channels**, the construction must be as solid as possible, and the stream bed must have a uniform slope of no less than ~ 5 ‰. The channel is to be vaulted over, so that the sun does not touch the water at all. [...]. If there are hills along the course between the city and the water source [...], an **underground** channel is to be dug, with the uniform slope described above. If the bed-rock is tuff or hard stone, the channel is to be cut directly in it; but if it is earth or sand, a vaulted channel with floor and walls is to be built in the tunnel. [...]. Vertical shafts are to be cut from the surface every one *actus* (~ 35 m).'[2]

Subsequently, Vitruvius describes in detail aqueducts made of lead pipes, before giving some specifications regarding terracotta pipes. He omits only stone and timber pipes.

Generally speaking, the earlier Roman aqueducts do follow the descriptions of Vitruvius – who, surprisingly enough, does not clearly mention water-supply-bridges in his text.

An exception might be a short and indirect comment of his (8,6.5): 'If [between the source and the city] exist valleys ('intervalla') then it is necessary to elevate the conduit by means of a substructure so that a smooth flow is achieved'.[3] This comment consists a rather inadequate reference to a possible bridge that is. This is perhaps due to the fact that during the 1st century BC, Pax Romana was not yet well established, and the risk of inimical destruction (or water contamination) of surface aqueducts was perhaps still probable, as it was during the Greek era. Another possible influence of previous Greek technical rules

[1] This is the typical Greek tapping, as for example behind the earlier krēnē, known as the 'krēnē of Theagenēs', in Megara, dated in 6th century BC, cf. Augerinou 2017: 44-48.
[2] Translation copied from Humphrey *et al*., 1998: 295.
[3] Translation based on the views of P. Lefas 1998: 187.

on Vitruvius' opinions, may be his subsequent recommendation regarding the use of 'inverted siphons' when a ravine ('vallum') is to be crossed (8.6.5): 'But when long ravines exist, then we direct the conduct to the slopes [and] when it reaches the depth [of the ravine], we construct a not high substructure, so that a smooth flow is achieved in the greater possible length; [...] this is what the Greeks call κοιλίαν'.[4] In this passage of Vitruvius, a tendency to avoid the construction of a high and long bridge could be observed, preferring the adoption of the Greek solution of an inverted siphon of pipes under pressure, instead of a very high bridge.

Nevertheless, the aqueducts built in the mainland and island Greece during the Roman period cover all types of construction (including water conduit bridges) – with the exception of lead pipes, which seem not to have been used so frequently. The chronology of construction of these aqueducts (after the 1st century AD) explains the important developments made in Roman technology after the time of Vitruvius.

1. Roman Aqueducts in Greece

Aqueducts built during the Roman times in the mainland of Greece, the Islands and in the Greek Cities in Asia Minor, were (partly at least) a development of Greek (Archaic, Classical and, especially, of Hellenistic) Engineering. This simple fact may be helpful in comprehending some of the Roman technologies initially used, as well as some of the characteristics of local technicians in Roman dominions. This may be for instance the case with the use of strong stone-pipes in inverted siphons (as in the Hellenistic aqueducts indicated by Hodge)[5] or the use of lead pipes (as in the Hellenistic aqueduct under pressure in Pergamos).[6]

It is worth noticing, however, that these remarkable examples of Greek hydraulic engineering are taken from Greek cities outside the mainland. Having this in mind, it can be noted that, since mainland Greece had not much benefitted of the significant Hellenistic developments in Alexandria and Asia Minor (both in economic and technological terms), the influence of the Roman hydraulic technology was much more clearly observed in Greece than in the Greek regions abroad.

Scope of this first Part of the present volume is the description of significant aqueducts built in Greece during the Roman period. There are of course several equally important Roman aqueducts too, as shown in a broader catalog here below (cf. Table 1). It is however thought that the examples selected in this book are in fact the most representative of the entire period. We welcome the contributions of **Asimina Kaiafa-Saropoulou** on the ***Vaulted-Roof Aqueduct Channels in Roman Macedonia***, of **Constantinos Zachos and Leonidas Leontaris** on the long awaited ***Aqueduct of the Actian Nikopolis***, of **Manolis Manoledakis** regarding the ***Water Supply of Roman Thessaloniki***, giving emphasis on the Hortiatis' Aqueduct, of **Eustathios Chiotis** and his treatise on the renowned ***Hadrianic Aqueduct of Athens and the Underlying Tradition of Hydraulic Engineering***, of **Yannis Lolos** on the ***Hadrianic Aqueduct in Corinth***, of **Yannis Kourtzellis, Maria Pappa and George Kakes** and their study on the unique ***Roman Aqueduct of Mytilene***, of T**elauges** N**. Dimitriou** and his presentation on the ***Roman Aqueduct of Samos***, and lastly, of **Amanda Kelly** and her enlightening study about an ***aqueduct through the Highlands*****,** presenting us ***the Water Supply for elevated Lyttos*** **(Crete)**.

The above mentioned authors of the respective chapters are to be complimented for the detailed presentations they offered and the scientific methodology they followed in their research. I am sure that the scientific value of these chapters will be greatly appreciated by their readers, as it was by me.

In what follows, an attempt is made to summarise the main characteristics of the aqueducts presented in Part I, in an effort to move from the specific to the more general.

Table 1: An abbreviated catalog of Roman aqueducts in Greece (based on Lolos 1997: 302, modified)

[4] 'κοιλία' in Greek stands for the Latin 'venter' (=belly, in English).
[5] Hodge 1992: 33, l. 36.
[6] Garbrecht 1987: 26.

No	Location	Period
1.	Dion (Macedonia)	2nd century AD
2.	Philippi (Madeconia)	2nd century AD
3.	Hortiatis (Thessalonikē)	(1st century AD)
4.	Samothrace (Thrace)	(Roman)
5.	Demetrias (Thessaly)	(Roman)
6.	Glyky (Epiros)	(?)
7.	Goritsa (Thessaly)	(?)
8.	Nikopolis (Epiros)	1st and 2nd century AD
9.	Athens	2nd century AD
10.	Delion (Boeotia)	(?)
11.	Eleusis	(Roman)
12.	Lamia (Central Greece)	(Roman)
13.	Marathon (Attica)	2nd century AD
14.	Megara	(?)
15.	Piraeus	(Roman)
16.	Corinth	2nd century AD
17.	Argos (Peloponnese)	2nd century AD
18.	Gytheion (Peloponnese)	(Roman)
19.	Hermionē (Peloponnese)	(Roman)
20.	Kalabryta (Peloponnese)	(?)
21.	Loukou (Peloponnese)	(Roman?)
22.	Mantineia (Peloponnese)	(?)
23.	Megalopolis (Peloponnese)	(Roman)
24.	Olympia (Peloponnese)	2nd century AD
25.	Patras (Peloponnese)	(Roman)
26.	Sikyon (Peloponnese)	(Greek + Roman)
27.	Sparta (Peloponnese)	2nd century AD
28.	Kos (Aegean)	(Roman)
29.	Leros (Aegean)	(Roman)
30.	Mytilēnē (Aegean)	2nd century AD
31.	Samos (Aegean)	(4th century AD?)
32.	Chersonēsos (Crete)	1st / 2nd century AD
33.	Eleutherna (Crete)	(Roman)
34.	Elyros (Crete)	(Roman)
35.	Gortys (Crete)	(Roman)
36.	Inia (Crete)	(Roman)
37.	Knossos (Crete)	1st to 2nd century AD
38.	Koufonisi (Crete)	(Roman)
39.	Lyttos (Crete)	2nd century AD
40.	Basilikē (Crete)	(Roman)

2. Baths, Fountains or Individual consumers

The scope of these relatively large aqueducts cannot always be identified. It all depends on Archaeological evidence based on the remains of public baths, public fountains and large water reservoirs, serving an internal network or directly the city's Agora.

In the cases described in this volume, most of these scopes are served, but in some cases information on these matters is rather missing. On the other hand, many of the authors in this Part (I) of the volume are indeed providing us with valuable historical details regarding the activities of the inhabitants of the cities concerned, as a way to estimate (though indirectly) their consumption needs in water, as well as to propose possible chronologies for the construction of the discussed aqueducts.

3. Water catching

In most of the Roman aqueducts presented in this book, natural springs are yielding their waters to the conduit, directly or after a small reservoir. In Macedonia, however, catching directly from rivers was also effectuated. Finally, tapping of underground water by means of interconnected wells (or also along a permeable tunnel-work) is described in some important cases. The authors participating in Part I of this volume are making a commendable effort to identify the specific areas where water catchments were located each time. And this is a particularly difficult task because, among other reasons, the level of the underground water horizon and the capacities of the aquiferous zones have drastically changed through time. Furthermore, it is worth noticing that, in some cases, the initially drawn water quantities were further increased by means of smaller transversal or parallel secondary aqueducts, constructed along the main aqueduct.

4. The Length of the Aqueducts

Several historical developments resulted in a considerable increase of the distances where water sources were sought during the Roman period – when compared to Classical Greek or even Hellenistic times: the needs in water supply were increased, both because of the city-population growth and because of the changes in bathing-culture. Moreover, better hydraulic technology and enhanced security measures taken regarding neighbor cities' hostilities of the past, have also contributed to the lengthening of aqueducts. The 1km of Peirene (Corinth, 7th century BC), 1,5km of Megara (6th century BC), the 2,5km of Samos (6th century BC), the 7,5km of Peisistration in Athens (6th century BC), the 11km of Naxos (6th century BC), were already surpassed by the Hellenistic period – even without the extreme case of the Pergamos aqueduct system (with one of its aqueducts being 25km long). In the present volume the records are different: Dion 10km, Samos 15m, Hortiatis 20km, Hadrianic aqueduct of Athens 20km, Lyttos 22km, Mytilene 33km, Nicopolis 70km, Corinth 85km. One can clearly detect a typically Roman 'magnification' in these cases.

5. Construction technology

As is described within this volume, traditional and modern construction methods were employed in the construction of aqueducts both in mainland and island Greece during the Roman period:

If the route of the aqueduct follows the topographic contours of the **ground**, it is possible to construct the conduit (almost on the surface of the ground) either as:

a) a simple masonry-revetted ditch on a strong soil, or as
b) a trapezoidal (or rectangular) conduit carved on a rocky slope.

More frequent however is the construction of low-depth **buried** conduits:

c) In a 'cut and cover' excavation, a rectangular masonry conduit is constructed, high and large enough to be visited and maintained; its cover may be a half-circular vault or a stone-slab. Soil of variable thickness covers the conduit.

If however, hydraulic or geomorphological conditions require an **underground** course of the aqueduct,

d) the typical 'shaft-and-gallery' system is followed (a shaft is excavated, and from its bottom the worker digs the almost horizontal gallery up to the bottom of the preceding shaft),[7] or
e) a more deep tunnel is dug (with revetted or naked walls).
f) Nevertheless, when an intermediate valley is offered as a possible shortening of the entire aqueduct, then
g) the solution of an elevated channel is adopted, on top of appropriate walls or, mainly, **bridges** with arcades.

Finally, if a relatively narrow ravine is to be crossed,

h) an '**inverted siphon**' (pipes under pressure) is constructed close to the bottom of the ravine, in order to avoid the construction of a very high bridge.

Due to the meticulous work of all authors of Part I, the readers of this volume may find collected in the following Table (2) all the construction technologies followed by the Roman aqueducts presented in this book.

Table 2: Construction Technologies

No	Aqueduct	On the Ground	Underground			On walls or on bridges	With Inverted Siphons
		In ditch or carved on the rock	Cut and cover	Shaft and gallery	Tunnel		
		a or b	c	d	e	f	g
1	Hortiatis			+		+	
2	Dion		+			+	
3	Nikopolis	+	(+)	+	+	+	
4	Athens			+			
5	Mytilēnē	+		+	+	+	
6	Corinth			(+)	+	+	
7	Philippoi Edessa		+				
8	Samos	+				+	
9	Lyttos	+		+		+	+

Some other technical details described in the corresponding chapters of this volume are as follows:

– manholes for cleaning (located approx. every 1 'actus' = 120 feet ~ 35m, or sometimes every multiples or submultiples of actus)
– deep wells for the aeration of deep tunnels,
– water towers installed at the juncture of abrupt directional changes (horizontally or vertically)
– impurities' settlement tanks (*piscinae liminariae*) are sometimes mentioned
– water reservoirs to feed an internal city-distribution network (*castella divisoria*) – although few of them have survived.
– secondary water reservoirs.

[7] For a discussion regarding the tendency for a broader use of the term 'qanat', see Chiotis 2017: 1-16 and Defteraios *et al.* 2017: 50-54, as well as the papers of M. Manoledakis and E. Chiotis in present volume.

6. Cross sections of conduits

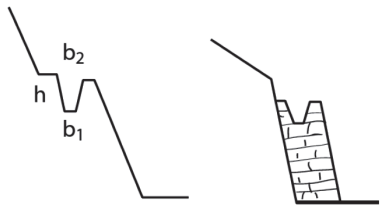
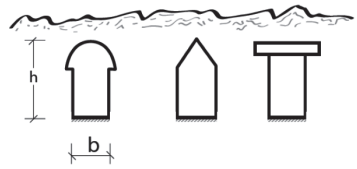
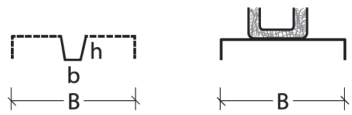
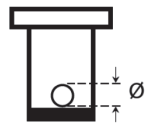
It needs to be reminded that in the case of free water flow in open channels, the geometrically available cross sections do not necessarily coincide with the 'hydraulic' cross section; the geometry of these conduits is imposed by practical rules regarding:

- minimal dimensions for digging or carving the channel,
- space needed to apply the masonry-covers of the walls of the channel, and
- space needed for a person to walk in underground conduits for cleaning and possible repairs.

In many cases, however, terracotta or lead pipes are accommodated within such larger conduits, operating under pressure or even under free flow.

Based on the detailed information offered by our Authors, the following summarized Table 3 may be prepared, regarding the cross sections of conduits of Roman aqueducts in Greece.

Table 3: Typical cross-sections of conduits (indicative dimensions)

Open channels[(a)] (carved on rocky slopes or built on top of retaining walls)	
Masonry revetted channels[(b)]	
Channels on walls or bridges[(c)]	
Conduits including pipes[(d)]	e.g. 
(a) b_1 ~ 0,20 to 0,30 m , b_2 = 0,30 to 0,40 m , h ~ b (In the aqueduct of Corinth b_1 > 1,00 m)	
(b) b ~ 0,40 to 0,80 (1,30) m , h ~ 1,00 to 1,80 m (In Corinth, Eleutherna and Elyros, the width was larger than 1 m.	
(c) b ~ 0,35 to 0,60 m , B ~ 2,00 to 5,00 m , h »	
(d) Ø ~ 0,20 m	

	max. wall thickness	max. height
Lyttos	2,4 – 4,5 m	8,10 m
Hortiatis	5,00	20,10
Corinth	2,90	11,20
Mytilene	2,50	25,0
Samos*	7,00	21,7
Nikopolis	(3,00)	7,80

Dimitriou 2003: 206, drawing 19.

7. Some characteristics of bridge-aqueducts

It seems that the geometrical data of the structures were decided as a function of the height of the bridge, the span of the arcades, the existence of buttresses and (mainly) the employed masonry-building technique (ashlar or rubble masonry). That is why a considerable variability is observed in the wall-thickness of the bridge-aqueducts described in this volume:

The case of the Mytilene aqueduct is however particular; it seems that this aqueduct is the most 'monumental' of the preserved Roman bridges in mainland and island Greece and one of the two with three 'floors' (zones) of arcades.[8] Despite its rather insufficient inspection level, it was the only one with such a high slenderness, since the 'height-to-thickness' ratio equals to 5, whereas in all other aqueducts the applicable ratio is lower than 4.

Details regarding the foundations of the piers of these bridges are not easily available, at least on the basis of Archaeological excavations, which as understandable, are very difficult to conduct.

This short paragraph cannot be closed without a brief reference to the '**substitute**' of a water-bridge, that (in the case of a deep and long ravine) can be an '**inverted siphon**', as it is described by Vitruvius (8.6.5). Among the aqueducts presented in this Volume, it seems that only in the case of Lyttos an inverted siphon was identified near Terazi, confirmed also by one stone-pipe (perforated diameter 0.22m, minimum wall thickness 0.15m) found *in situ* by Oikonomakis (1984).[9] Assuming a tensile strength of that soft rock equal to f ~ 2 N/mm^2 and following simple calculations[10], it may be estimated that this pipe was able to withstand a hydrostatic pressure of 70m of water, with a safety factor equal to 2. It is obvious that the actual hydrostatic pressure in this case was considerably lower.

For the sake of completeness on this subject, it is very interesting to note that in the island of Lesbos (cf. the aqueduct of Methymna, mod. Molyvos), a series of such perforated stone cubes were found (internal diameter 8cm), with recessed male-female joints.[11]

8. Building Materials

At this point it is considered appropriate to present a brief summary of building materials employed in the Roman aqueducts described in this Volume.

- Blocks:
  - Stones (ashlar or rubble)
  - Bricks (thick and large)
- Mortars:
  - Binders + Sands
- Binders:
  - Lime
  - Lime and crushed ceramics
  - (Lime and puzzolan?)
  - Clay
- Plastering and pointing material:

[8] The other is the aqueduct of Samos, at the 'Yianniou-bridge' (Dimitriou 2003: 206).
[9] Oikonomakis 1984: 66-69.
[10] Tassios 2006: 21.
[11] I am indebted to Dr Yannis Kurtzellis for the bibliographical information, and to Prof. Yannis Lolos who mentioned this archaeological find to me.

- Fine grain hydraulic mortar. Special care was taken against possible cracking at the corners of vertical walls and the bottoms of conduits.

Arcades and vaults were made on timber-formwork, radially arranging large thick bricks or flat stones with thick intermediate mortar layers.

Remnants of local quarries and lime-kilns are occasionally identified along the course of the aqueducts.

9. Water capacity of the aqueducts

As it is well known, the water capacity of a conduit depends

(i.) on its hydraulic cross section
(ii.) on the roughness of the walls of the channel
(iii.) on the 'hydraulic gradient' of the aqueduct, and
(iv.) on the various water losses, such as evaporation, leakage through joints; intermediate illegal water-connections may sometimes be also important.

Regarding the hydraulic cross section, in ancient open channels we generally ignore the average flow **depth**; and this may result in very large errors in calculating both the velocity and the capacity of the channel.

On the contrary, regarding the roughness of the internal walls of the channel, we may make better estimates – assuming however a certain level of cleaning and maintenance care (including also measures against possible sprouting of plants in the conduit).

Finally, geomorphological and hydraulic conditions may shape the value of the hydraulic gradient 'J' (i.e. the ratio between the altimetric difference between the 'starting' and the terminal point of the aqueduct, over the length of the aqueduct between these two points). The selection of these two reference points should however be carefully made, so that no turbulent stretches are included between them. Evidently, this is not an easy task for us regarding a dry ancient channel.

Due to all these difficulties and uncertainties, our attempts for an *a posteriori* calculation of the possible water-capacities of ancient conduits are rather alleatoric.

Nevertheless, our interest to acquire a broader understanding of the function of ancient aqueducts necessitates the knowledge of an even roughly estimated margin of their water-capacity. Such knowledge can also be used to check – or complete – our information on the number of inhabitants of the ancient city, as well as their 'water culture'.

From this point of view, it is evident that the valuable data presented by all authors contributing in this Volume, constitute a sound basis and provide the 'impetus' for further research on the field of water archaeology, emphasizing on aqueducts in the Greek provinces of the Roman Empire.

Theodosios P. Tassios
Civil Engineer
Professor Emeritus
National Technical University, Athens, Greece
President of the Association of Ancient Greek Technology Studies
Member of the Academy of Sciences of Turin (Italy)
tassiost@central.ntua.gr

Bibliography

Augerinou, P. 2017. The Archaic underground aqueduct in Megara, in Chapter 4: An Updated Appraisal of Ancient Underground Aqueducts in Greece. In: A. N. Angelakis, E. D. Chiotis, S. Eslamian and H. Weingartner (eds) *Underground Aqueducts Handbook*: 44-48. Boca Raton, FL: CRC Press.

Chiotis, E. 2017. Underground Aqueducts: Types, Definitions and General Conclusions. In: A. N. Angelakis, E. D. Chiotis, S. Eslamian and H. Weingartner (eds) *Underground Aqueducts Handbook*: 1-16. Boca Raton, FL: CRC Press.

Defteraios, P., Chiotis, E. and Mamassis, N. 2017. Underground evidence on the tunneling technique of the Hadrianic aqueduct of Athens, in Chapter 4: An Updated Appraisal of Ancient Underground Aqueducts in Greece. In: A. N. Angelakis, E. D. Chiotis, S. Eslamian and H. Weingartner (eds) *Underground Aqueducts Handbook*: 50-54. Boca Raton, FL: CRC Press.

Dimitriou, T. 2003. *Το Ρωμαϊκό υδραγωγείο της Σάμου*. Athens: 'N. Dimitriou' Samos Cultural Institute.

Hodge, T. 1992. *Roman aqueducts and water supply*. London: Duckworth.

Humphrey, J. W., Oleson, J. P., Sherwood A. N. 1998. *Greek and Roman Technology: A Sourcebook. Annotated Translations of Greek and Latin Texts and Documents.* London: Routledge.

Garbrecht, G. 1987. Die Wasserversorgung antiker Pergamon. In: Frontinus Gesellschaft e. V. (eds) *Die Wasserversorgung antiker Städte: Pergamon. Recht / Verwaltung. Brunnen / Nymphäen. Bauelemente:* 11-48. Mainz-am-Rhein: von Zabern Verlag.

Lefas, P. 1998. *Μετάφραση και σχολιασμός του Βιτρουβίου, Περί Αρχιτεκτονικής*, τ. I (Βιβλία 1-5), τ. II (Βιβλία 6-10). Athens: Plethron Editions. (2001, 2nd Edition).

Lolos, Y. 1997. The Hadrianic aqueduct of Corinth. *Hesperia* 66.2: 271-314.

Oikonomakis, N. E. 1984 .Το Υδραγωγείο της Λύκτου. *Lyktos* 1: 66-99.

Tassios, T.P. 2006. Selected topics of water technology in Ancient Greece. In: A. N. Angelakis and D. Koutsogiannis (eds) *1st IWA International Symposium Water and Wastewater Technologies in Ancient Civilizations. 28-30 October 2006*: 3-26. Herakleion.

Introduction II.
Roman Monumental Fountains (Nymphaea) in Greece

Georgia A. Aristodemou

Monumental fountain structures, built by Emperors and wealthy patrons in cities throughout the Roman Empire, have always been striking features of Roman architecture. These imposing – often multi storied – fountain structures, not only became a trend in the Roman East, but they contributed greatly to the formation of a luxurious urban environment. During the last four decades scholars studying nymphaea focused mainly on producing a relevant terminology and establishing their architectonic typology, along with their evolution in form and design. Only the past few years, research extended to issues such as their sculptural decoration, their aesthetics, their interaction with their surrounding environment and the impact nymphaea had upon the local communities.

Research has been greatly developed, especially regarding the eastern part of the Roman Empire. However, modern scholarship has more to present about the Asia Minor, the Levantine and the North African provinces rather than the Greek provinces.[1]

There is a definite and considerable gap in modern archaeological research, discussion and bibliography, regarding monumental fountain structures in Roman Greece. [2]

This volume attempts to fill this gap, by gathering studies from scientists, all dedicated to the study and development of fountain archaeology in Greece during the Roman period. It is self-evident that not all monumental fountains were included in this collective work. One may observe, for example, the absence of the great Nymphaeum of Herodes Atticus located in the sanctuary of Zeus in Olympia. The main reason is that this monument was fully and in details published and presented as early as 1984 by Renate Bol.[3] Any addition to the information would not be significant. Or, the absence of the renowned Corinthian fountains, which were all thoroughly presented a few years ago by Betsey Robinson.[4] On other reason is that even though numerous fountains dated in the Roman period are excavated nowadays during rescue or systematic excavations in mainland and island Greece, unfortunately – and perhaps due to the lack of knowledge, or scientific resources – they either remain unpublished or they are poorly understood and scatterly presented. As a result the archaeological community is deprived from the opportunity of a better comprehension of these important monuments and their evolution in the Greek territories.

Under the above mentioned limitations, we decided to present here three kinds of studies; theoretical approaches and overviews (on sculpture, aesthetics, contextualization), discussions of specific monuments, under a new consideration (Messene, Gortyn), and entirely new presentations of so far unpublished monuments (Nikopolis).

Six papers were gathered in this Part (II) of the volume to discuss various aspects of the monumental nymphaea in Roman Greece. All six papers consider monumental nymphaea and luxurious fountains as

[1] For example, Dorl-Klingeschmid, Cl. 2001. *Prunkbrunnen in kleinasiatischen Städten. Funktion im Kontext*. Studien zur antiken Stadt 7, Bayerische Akademie der Wissenschaften, München; Uğurlu, Nur Banu, 2009. *The Roman Nymphaea in the cities of Asia Minor: Function in Context.* Saarbrücken; Richard, J. 2012. *Water for the City, Fountains for the People. Monumental Fountains in the Roman East: an Archaeological Study of Water Management.* Studies in Eastern Mediterranean Archaeology (SEMA), 9. Brepols.

[2] Longfellow, B. 2011. *Roman Imperialism and Civic Patronage Form, Meaning and Ideology in Monumental Fountain Complexes*. Cambridge University Press; Robinson, B. A. 2011. *Histories of Peirene: A Corinthian Fountain in Three Millennia*. Princeton: ASCSA; Aristodemou, G. 2012. *Ο Γλυπτός Διάκοσμος Νυμφαίων και Κρηνών στο Ανατολικό Τμήμα* της Ρωμαϊκής Αυτοκρατορίας [*Sculptural Decoration of Monumental Nymphaea in the Eastern Provinces of the Roman Empire]*. Thessaloniki : Kornelia Sfakianakis Publications. Rogers, D. K. 2015. *Water-Display and Meaning in the High Roman Empire.* Unpublished PhD dissertation, University of Virginia.

[3] Bol, R. 1984. *Das Statuenprogramm des Herodes-Atticus Nymphaeums.* Olympische Forschungen, Band XV. Berlin: Walter de Gruyter.

[4] Robinson, B. A. 2001. *Fountains and the Culture of Water at Roman Corinth*. Unpublished PhD dissertation, University of Pennsylvania; Robinson, B. A. 2011. *Histories of Peirene: A Corinthian Fountain in Three Millennia*, ASCSA, Princeton.

reflections not only of the architectural aesthetics developed in the Greek provincial cities of the Roman Empire, but also of the social, political and religious life of their citizens. They are the following:

Dylan Kelby Rogers (*Shifting Tides: Approaches to the Public Water-Displays of Roman Greece*), is the new entry in scholarly discussion regarding the role of nymphaea into their urban environment. Since the study of Roman water-displays is constantly evolving (with research being conducted on the terminology of the structures, their typologies, their sculptural programs, and their impact on the social and physical landscapes surrounding them), he is approaching the subject under a new aspect, focusing on 'aesthetics'. His present paper focuses on a survey of the terminology used and the historiography therein, so that water-displays that until now have not received a great deal of attention (in religious, civic, and entertainment-related contexts) should also be considered. With his work, he poses several and significant new ways to advance the study of public Roman water-displays in Greece.

Georgia Aristodemou (*Fountain Figures from the Greek provinces: monumentality in fountain structures of Roman Greece as revealed through their Sculptural Display Programs and their patrons*), focuses on the definition of the term 'fountain figures', namely sculptures with a visible water outlet ascertaining a spouting function or sculptures that regardless their function derive from an elaborated fountain. Next, she discusses the presence and function of sculptures within the fountain structures based on their direct (organic) or indirect (thematic, regional) relation with water and nature. Imperial and private portraiture are also discussed since they underline the Imperial power and the prestige of local Elite. Issues about sculptural assemblages and the way these were carefully arranged to highlight the prestige of the local communities and sponsors are also presented. The significance of choices on a local, regional, imperial level allow us to study sculptural display programs of monumental nymphaea as a reflection of the patrons and the city's status and power.

Constantinos Zachos and Leonidas Leontaris (*The Aqueduct of Actian Nikopolis),* are participating with the most recent and complete presentation of the aqueduct of Nikopolis (the largest aqueduct of Roman Greece). Even more important is the fact that they supplement their study with a preliminary but extremely significant description of the twin monumental nymphaea of Nikopolis – two fountain structures that were directly supplied by the aqueduct and for many years have engaged scholarly discussions regarding their initial architectural form and their chronology (1st or 2nd century AD). We are privilege to have the excavators of these nymphaea reaching to concluding remarks regarding important questions about the nymphaea's building phases, their connection to the aqueduct, their dating and their association to the Hadrianic building program. It is needless to comment their valuable contribution to the archaeological discussion about monumental nymphaea in Roman Greece.

Susan Leigh *(The Monumental Fountain in the Athenian Agora: Reconstruction and Interpretation)*, presents us with an up to date reconstruction and interpretation of the Monumental Fountain in the Athenian Agora, the so-call Southeastern Nymphaeum. In the last five years the architecture of and various issues regarding the monumental fountain in the Athenian agora, a building not preserved above foundation level, leaving all possible reconstructions largely hypothetical, have undergone renewed scrutiny. S. Leigh provides us with a fresh look at this extraordinary edifice after presenting earlier discussions and recent reconstructions (especially regarding the existence – or not – of a second floor). More specifically, she reconsiders the evidence and possibilities for the architecture and decorative program of the Athenian fountain, and the degree to which its reconstruction based on the Olympia structure is likely. Additionally, she postulates the possible water technology utilized in the structure, a topic largely ignored in previous studies. She also discusses the meanings behind the siting of the 'nymphaeum', its imperial connections, and how the monument and its supply aqueduct visually changed the southeastern Agora space and the important ceremonial approach to the Acropolis, the Panathenaic Way. This focused restudy allows the building to be better understood within its context in the Imperial Greece as well as within Hadrian's program of Athenian Euergetism.

Mario Trabucco della Torretta (*New water from old spouts: the case of the Arsinöe Fountain of Messene*), reconsiders an old monument, the Arsinöe fountain in Messene – an urban monumental water facility originally built at the end of the 4th century BC and transformed several times afterwards, both using the same architectonic members and adding new ones. In his paper, he proposes a new analysis of the two Roman phases of the specific fountain. The first Roman transformation of the building during the second half of the 2nd century BC is examined regarding its architectural characteristics and set in the broader context of the so called 'Romanisation' of the province of Achaia. Trabucco della Torretta is comparing the evidence from the Arsinöe fountain with similar cases in Greece and the other provinces (Asia Minor, Sicily), whereas he is posing questions on how the Romanisation process – a process accomplished throughout the Roman world also through the establishment of Roman architectural models in the newly annexed provinces – can be detected at the provincial landscapes. In accordance to this, he examines the second large-scale refurbishment of the fountain (during the second half of the 1st century BC), underlining the transformation of urban monumental fountains from plain and utilitarian buildings to places of display and propaganda, and their connection with their urban environment.

Brenda Longfellow (*Reflecting the past: the nymphaeum near the so-called Praetorium at Gortyn*), discusses the single-storey Pi-shaped nymphaeum (F25) near the so-called *Praetorium* in Gortyn, which was built by an unknown patron in the second half of the 2nd century AD. At this time, it was adorned with an extensive sculptural group that included seated muses, fountain sculptures of gods, and portrait statues that presumably portray the patron of the monument and members of his family. Standing in the civic center and facing the so-called *Praetorium* across a large street that traverses the city, the fountain was highly visible in the cityscape, where it provided a convenient source of potable water as well as an eye-catching artistic water display. Sometime between the 5th and 8th century AD, the open-air settling basin was enclosed and the edifice transformed into a barrel-vaulted reservoir, where, however, the 2nd-century sculptural group was re-erected along the colonnaded façade wall of the transformed monument.

Longfellow's paper examines the ancient and late-antique phases of the monument in order to answer the question of why a late-antique patron would re-erect the sculptural group at all. According to her, the sculptural group's resurrection should be attributed to the connections of the late-antique patron to the specific community – as well as to the late-antique imperial legislation that repeatedly restricted the removal of statues and other architectural elements from public buildings and urban centers across the Empire.

.....

It is now comprehended that monumental nymphaea are centrally located in major cities of the Roman East and are usually financed by the Emperor, the city, or the local Aristocracy. Financing the construction of a nymphaeum and (or) its sculptured decoration is a politically motivated action, whether the benefactor is the Emperor himself, the city, or a private individual. Evidently, monumental nymphaea are actually products of specific historical and social conditions. In this Part (II) of the collective volume an attempt was made, to reconstruct the social, political as well as cultural role that these edifices held in the Greek provinces. The main goal was not only to fill an essential scientific gap but also to launch the discussion among experts regarding fountain archaeology in Roman Greece.

Dr Georgia A. Aristodemou
Researcher of Roman Archaeology
School of Humanities
International Hellenic University, Thessaloniki, Greece
E-mail: g.aristodemou@ihu.edu.gr; garistodemou@gmail.com
www.hum.ihu.edu.gr