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How Water Distribution Modeled the Architecture of a City. The Emblematic Case of Ancient Pompeii

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ABSTRACT

The abundance of water in the homes or at the doorstep of every inhabitant of the city is one of the most striking connotations of ancient Pompeii. Two millennia ago there was an aqueduct of about 100 km that conveyed the pure water of the source near Serino to the Piscina Mirabilis of Miseno and, through a ramification, to Pompeii as well. For this reason many Pompeian homes had running water conveyed by one of the most sophisticated urban distribution networks in the world. Pompeii's water distribution system gave priority to public use at the fountains and drinking troughs, and left the rest, which was still quite abundant, for private dwellings. An ingenious system of arrest (valves and faucets) ensured that there was no waste.

Keywords: *Pompeii,water distribution, fountains*

INTRODUCTION

In the autumn of the year 79 A.D. a catastrophic eruption of Mt. Vesuvius, a volcano that had been quiescent for more than 500 years, destroyed the Roman cities of Herculaneum and Pompeii in just a few hours. The manner in which this enormous tragedy took place was not the same in the two inhabited centers: for a lava of thick mud enveloped Herculaneum, while Pompeii was buried under a layer of lapilli and ashes. Although this led to the irremediable disappearance of both cities, from an archeological perspective it became very clear, about 17 centuries later, that their excavation would be incomparably different. In Herculaneum, whose location was revealed when several wells came to light around the mid 1700s, the masonry scraps and domestic fragments were found englobed in a hard gangue of tufa stone, from which they had to be extracted and recomposed with painstaking care. In Pompeii, on the other hand, it was sufficient to remove the fragmented shroud of volcanic dejections to once again reveal the roads, houses and walls of the city, obviously reduced to ruins but still exhibiting their extraordinary and singular connotations.

Pompeii, like Herculaneum, had not been destroyed by one of the many wars followed by the inevitable looting and abandonment, and the slow removal of all that could still be useful. Both cities vanished in the fullness of their frenetic daily life but, as per the previous statement, though the ruins of Herculaneum could only be slowly and partially restored to be admired by all, such was not the case for Pompeii. There were no great difficulties, except for the quantity, in removing, shovelful by shovelful, the layers of lapilli that soon unearthed what Mt. Vesuvius had sealed away on that far away autumn. The roads, houses, thermal springs, theatre and amphitheater reappeared, complete with related installations and accessories that, because of the optimal status of preservation, were attentively studied.

For visitors who came from all corners of the globe in the past two centuries it was a superb feeling to wander over the paving stones of those streets, an exhiklirating emotion to enter homes so recently abandoned.

Figure1a. *Pompeii plaster mouldings.*

Figure1b. *Hercolaneum fragments of human skeletons. The comparison highlights the differences in the burial of the two cities.*

But for scholars it was an unhoped for opportunity, a gift of nature, to finally be able to learn from the existential reality of a Roman city buried in the fullness of its daily activities, along with many of its inhabitants that thanks to an ingenious technique reemerged as pale ghosts in the spasms of their final agony. Studies, like visitors, multiplied, but some sectors, perhaps because they were less romantic, remained along the periphery of special interests, restricted to the attention of a few specialists.

These were the remnants of the technology that existed in Pompeii, an eloquent testimony of the socio-cultural level that had been reached in the great Empire. Symbolic is the case of the city water network, with its branches, piezometric turrets and its diversified consumers, connected by standardized pipes of different diameters, provided with stop keys, also of standardized size, that only required a thorough cleaning to once again be operational.

Since the exploration of Pompeii is of a thematic nature, these are the vestiges of urban networks to be emphasized, for they represent, to all modern technicians a sort of genealogy of forerunners whose existence is often ignored[1].

Water and Civilization

When the Greeks settled in the primitive village at the foot of Mt. Vesuvius, Pompeii acquired the typical connotations of the Greek colonies. The Forum was erected on a sort of anomalous acropolis, a natural terrace formed by hardened lava and protruding towards the Doric temple offering a magnificent and unobstructed view of the gulf and thus a strategic observation point for urban defence.

The lava from the prehistoric eruptions that had covered the south-eastern area up to half a kilometre from the coast, near the mouth of the river Sarno, made it the most inviolable portion of the city whereas in the northern section protection was provided by sturdy fortification walls which were regularly upgraded. Within a short time, Pompeii was enclosed within fortified walls extending to 3,3 km and the settlement was split along an almost axial north–south line which would later become the main road, via Stabiana, spanning from the Vesuvio gate at an altitude of 42,30 m, to the Stabia gate, at an altitude of 8 m above sea level. While within the perimeter there was ample space for potential future urban expansion, in the mean time these areas were used for agricultural purposes to provide food for people and livestock during long sieges.

Although natural phenomena and the nature of the soil had shaped the early urban subdivisions of the city of Pompeii, it was water distribution that would definitively determine the configuration of the "Regiones" (neigborhoods)[2]. Indeed, a division into quarters seemed to exist during the time of the Samnites, persisting more or less unchanged during the Roman period as the use of place names, such as *Salinienses, Gampanienses, Urbulanenses and Forenses*, used to indicate the inhabitants of certain sections of the city, the "*vici*", rather than professional associations, would suggest[3].

The majority of homes exhumed from the ash and pumice under which they were buried by the 79 AD eruption, consisted mostly of Roman style houses and buildings erected after Lucius Cornelius Sulla's conquest (89 BC).

The Romans understood the essential role played by water in the life of a city[4]. Perhaps this was because they had founded their capital along the shores of a river, in accordance with a plan that would become common to all the major cities of Europe[5].

Before the development of aqueduct technology, the Samnites relied on local water sources such as springs and streams, supplemented by groundwater from privately or publicly owned wells[6,]and by seasonal rain-water drained from rooftops into storage jars and cisterns[7.] The reliance of ancient communities upon such water resources restricted their potential growth[8].Certainly, a constant concern of all the legionnaire technicians was that of bringing large quantities of potable water to the cities. When they had the option, the romans generally preferred to found their cities on plains when they had a choice[9]. One of the main reasons for this was that water distribution design was much easier than on any other geomorphologic configuration.

WATERWORKS AND POMPEII CITY

Assuming Pompeii's population to be around 20.00 inhabitants and estimating pro capita water consumption to be the same as that of a contemporary Rome, the need for water would amount to 10.00 cubic meters, a quantity that was at least equal to the volume of the *Piscina Mirabilis* in Miseno[10] or the pool in Albano. But, to date, there is no trace of such an artifact in Pompeii which would suggest that the flow governed by the tri- partitioning system was sufficient to meet the needs of the population[11].

Figure2a. *Pompeii. Exterior of three-way water distribution system.*

Figure2b. *Details of the three outlets.*

As the Romans considered the carrying capacity proportional to the section of the channel, the partitioning device generically called *"castellum aquae"* was divided into several smaller and geometrically equal basins[12]. The three basin version was the most widely adopted and was called *"tripartitore idrico"* (water tri-partitioning device)[13].The system is described by Vitruvio:

« […] Eaeque structurae confornicentur, ut minime sol aquam tangat. Cumque venerit ad moenia, efficiatur castellum et castello coniunctum ad recipiendam aquam triplex inmissarium, conlocenturque in castello tres fistulae aequaliter divisae inter receptacula coniuncta, uti, cumabundaverit abertremis in medium receptaculum redundet. Ita in medio ponentur fistulae in omnes lacus et salientes, ex altero in balneas vectigal quotannnis populo praestent, ex quibus tertio in domus privatas, ne desit in public, non enim poterint avertere, cum habuerint a capitibus proprias ductiones.Haec autem quare divisa constituerim, hae sunt causae, uti qui privatim ducent in domos vestigalibus tueantur per publicanos aquarum ductus[14]».

The tripartite of Pompeii is kept in perfect condition: within it, the incoming flow was made to expand in a circular, wide but not very deep pool divided into three equal currents by masonry dividers and channelled to feed a conduit. This device was set on the highest point of the city near the Vesuvio gate at an altitude of 42,30 m so that no section of the city would be excluded from the distribution[15].

Pompeii, in fact, due to its altitude differences had to resort to sophisticated hydraulic solutions to ensure adequate urban water distribution. with its 40 m altitude difference, the conduits and lead pipes could not sustain the water pressure load of 4kg/cmq, so a pressure reduction system needed to be devised[16].

The towers acted as pressure curtailing devices: the tank of about 1 square meter was covered and placed at the top of the 6 m tower, to accumulate the water flowing from a conduit (fed by the partitioning device or another tower) and feed it to the next tower below. The device ensured that the pressure in the pipes never exceeded the pressure produced by the height of a single tower and therefore 0.6 kg/cm2 which was compatible with their resistance. On top of these turrets was a lead caisson or water tank, open on top but protected by a lid, about one cubic meter in size. The feeding conduit issuing from the three-way distributor of the preceding turret emptied into this water tank and the conduit for the subsequent one would be supplied. The masonry parts unearthed in Pompeii are still in fair condition, though the metal parts of the pipes and boxes that existed at the time are now missing but did exist when they were first excavated and were even photographed. At the foot of the towers or sometimes adjacent to them the major public fountains were situated whereas the minor ones were at 40 m*. The former were fed by a pipe situated at the bottom of the tank and by excess water[23]. No private residence was more than 50 m from a public fountain[17].

Impact on the Built City

Water demand had increased with improved living standards especially among the affluent who lived in luxurious dwellings with decorative fountains which became a symbol of their wealth and social class[25]. It does not seem fortuitous that eight houses with decorative fountains were situated in Regio VI compared to the other Regiones that had between 1 and 3, seven of which faced via Mercurio[18].

«[...] It is easy to deduce that the proximity of the Vesuvio gate water distribution reservoir and the marked slope of the road in the direction opposite to that of the reservoir favoured the water supply of these areas. Furthermore, via di Mercurio was also a principle road due to its size and commercial importance. Those who lived there most probably owed their wealth to commerce and spent a great portion of it on the decorative apparatus of their homes where water played a dominant role»[19].

These observations are the starting point for the studies that aim at identifying and recording the links between the delineation of the urban quarters and the implementation of an urban water distribution system whose main conduits were directly accessible from the banks along the sides of the roads: a feature which had become necessary for maintenance purposes as the conduits and pipes were frequently and rapidly obstructed by the calcium carbonate that formed inside the pipes due to the low circulation pressure. Thus a new urban configuration emerges, spurred by a water demand for the decorative fountains[20] of the nouveaux riche rather than a demand for drinking water that was already available to the entire community even the most modest homes[21].

Insulae and Waterworks

According to Sextus Julius Frontinus, the water commissioner of Rome at the end of the first century AD and author of the De aquae ductu urbis Romae, the three ducts of the partitioning system for Pompeiii conveyed water to different destinations: the first to public fountains, the second to public baths for public revenue and the third to private houses that contributed revenue to maintain the aqueduct[22].

«Qui aquam in usus privatos deducere volet, impetrare eam debebit et a principe epistulam ad curatorem adferre; curator deinde beneficio Caesaris Caesaris protinus scriber. Procuratorem autem primus Ti. Claudius videtur admovisse, postquam Anionem Novum et Claudiam induxit. Quid contineat epistula, vilicis quoque fieri notumdebet, ne quando neglegentiam aut fraudem suam ignorantiae colore defendant. Procurator calicem eius moduli, qui fuerit imperatus, adhibitis Libratoribus signari cogitet, interdum maioris luminis, interdum minoris prop gratia personarum calicem probare. Sed nec statim ad hoc liberum subiciendi qualemcumque plumbeam fistulam permittatur arbitrium, verum eiusdem luminis quo calix signatus est per pedes

quinquaginta, sicut senatus consulto quod subiectum est cavetur»[23].

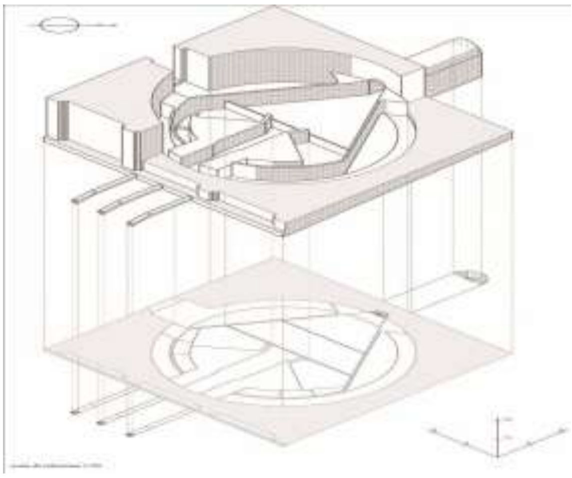

Figure 4b. *Axonometry of distribution system.*

Piezometric turrents or surge tanks were found during the excavations and another three or four are assumed to be still buried somewhere. The towers, however, were not found intact and the tanks and pipes were missing. The way the towers were arranged seems to confirm that the waterworks had independent ramifications (presumably three considering the characteristic of the castellum acquae)[24]. On the other part, Amedeo Maiuri he already had two suppositories[25] as pointed out elsewhere[26].The altimetry of the tower bases indicates that some are at the same sea level and others preceding them are at a lower level which would not be consistent with a cascade like arrangement[27]. Elevations of Piezometric Turrets

castellum aquae...... 42.28 m slm

piezometric turrets n°01……….. 35.38 m slm

piezometric turrets n°02……….. 32.68 m slm

piezometric turrets n°03……….. 28.91 m slm

piezometric turrets n°04……….. 24.31 m slm

piezometric turrets n°05.……… 30.40 m slm

piezometric turrets n°06……….. 24.46 m slm

piezometric turrets n°07……….. 35.69 m slm

piezometric turrets n°08……….. 38.07 m slm

piezometric turrets n°09……….. 29.90 m slm

piezometric turrets n°10…….. 30.00m slm

piezometric turrets n°11…….. 29.46 m slm

by the servey It is deduced piezometric turrets		
I° Acqa branch	II° Acqa branch	III° Acqa branch
n°7… 35.69 m	n°X … 40.00 m	n°08 … 38.07 m
n°1… 35.38 m	n°Y. … 36.00 m	n°09 ... 29.90 m
n°2… 32.68 m	n°Z… 33.00 m	n°10 … 30.00 m
n°3… 28.91 m	n°5… 30.40 m	n°11… 29.46 m
n°4… 24.31 m	n°W… 28.00 m n°6…… 24.46 m	

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As mentioned before, all the water towers had a limited but practically equal pressure in all parts of the city regardless of their position or altitude level. The constant flow in the pipes depended on their diameter and above all their relative distance to the castellum aquae. The first towers were not affected by the occasional yet inevitable water reductions due to cyclical oscillations, but the lower ones were fed cascade like from the preceding ones and so, as the level of water in their respective reservoirs got lower, it reduced the amount and then interrupted the flow of water conveyed to private homes which were connected via the piping at the upper margin of the reservoir whereas the public fountains remained unaffected because they were fed via the piping at the bottom of the reservoir.The specifications of the lead pipes soldered longitudinally were described in detail in chapter 26 of Frontinus's book: it is not a question of diameter measurements, in that the pipe sections are not circular but pear shaped but the width of the lead lining which due to the curvature generated them with a specific maximum diameter.

The way the towers were arranged seems to confirm that the waterworks had independent ramifications. The altimetry of the tower bases indicates that some are at the same sea level and others preceding them are at a lower level which would not be consistent with a cascade like arrangement.

The system catered to the Regiones rather than specific consumers as attested to by the many illegal connections that tapped the conduits and which no one was able to stop. A water concession was an actual concession and its issue was subordinate to specific merits, thus it was personal and temporary. It could be revoked or suspended at any time, without recourse, at least in theory and according to the information we have from Frontino[28].

One cannot ignore the fact that water was supplied at the expense of the State and had been conceived from the beginning as a public service as usum populi for the benefit of the entire community rather than to meet individual needs. In Pompeii's partitioning device, the lodgings, where the interception sluice gates could isolate any section and be closed as required, are clearly visible so it would be reasonable to assume that the primary castellum aquae was meant to convey the water to the above mentioned three destinations[37], which seems to be confirmed by the position and height of the water towers situated along the city roads. Full closure of any aqueduct for servicing would have been a rare event, kept as brief as possible, with repairs preferably made when water demand was lowest, which was presumably at night[29].

The cyclical water reductions of the system only affected the lowest parts of the town where the less affluent lived. This observation is to be considered one of the major reasons for the concentration of the dwellings of the wealthy (domus) near the first water towers where the water flow was never interrupted, and provides justification for the particular configuration of the Regiones.

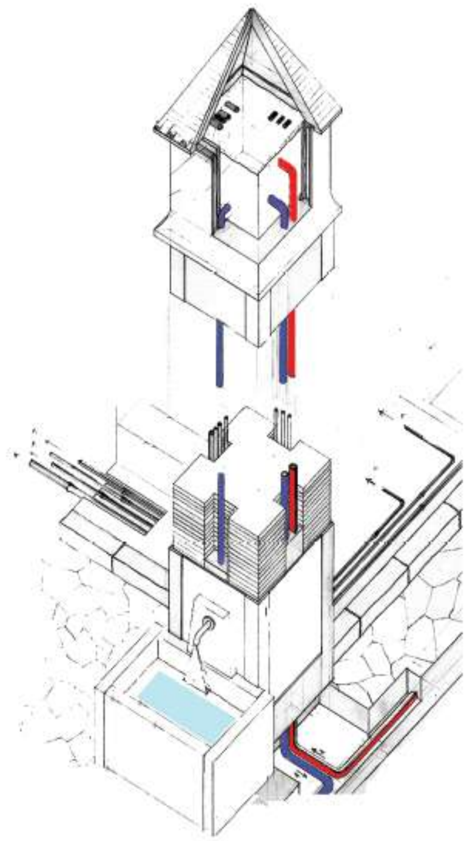

Figure5b. *Virtual reconstruction of the with the upper part located underneath the fountain. We presume that for hygienic reason the turrets had a pavilion covering on a wooden frame*.

Access to water, which was generally available to the entire community, had an impact on the class system of the city's inhabitants due to a pricing system based on distance from water cisterns.

It is therefore not surprising that, during the Roman period, the connection to the Serino aqueduct would reinforce within the plan of the city the formal division generated by the social classes[30].

It is no easy matter to determine which Regiones of the city were most densely inhabited, nor which homes were connected to the urban acqueduct (not solely for contingent reasons) and thus enjoyed a certain affluence. Unfortunately certain areas of Pompeii have yet to be excavated and those that were unearthed in previous centuries, using often ineffective means, have been damaged in several areas preventing us from achieving a gobal view of the actual residential status of the city and a comprehensive vision of the housing practices.

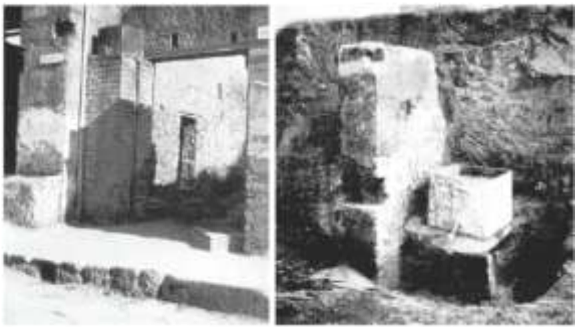

Figure6. *Historical photos of the excavation of a turret still containing the lead tank, subsequently lost.*

Bidon Estimated height of top container 1.0 m. [from Historical archive Mister Polisto Amitrano, courtesy concession].

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Figure7. *Pompeii, Stabiana Street.*

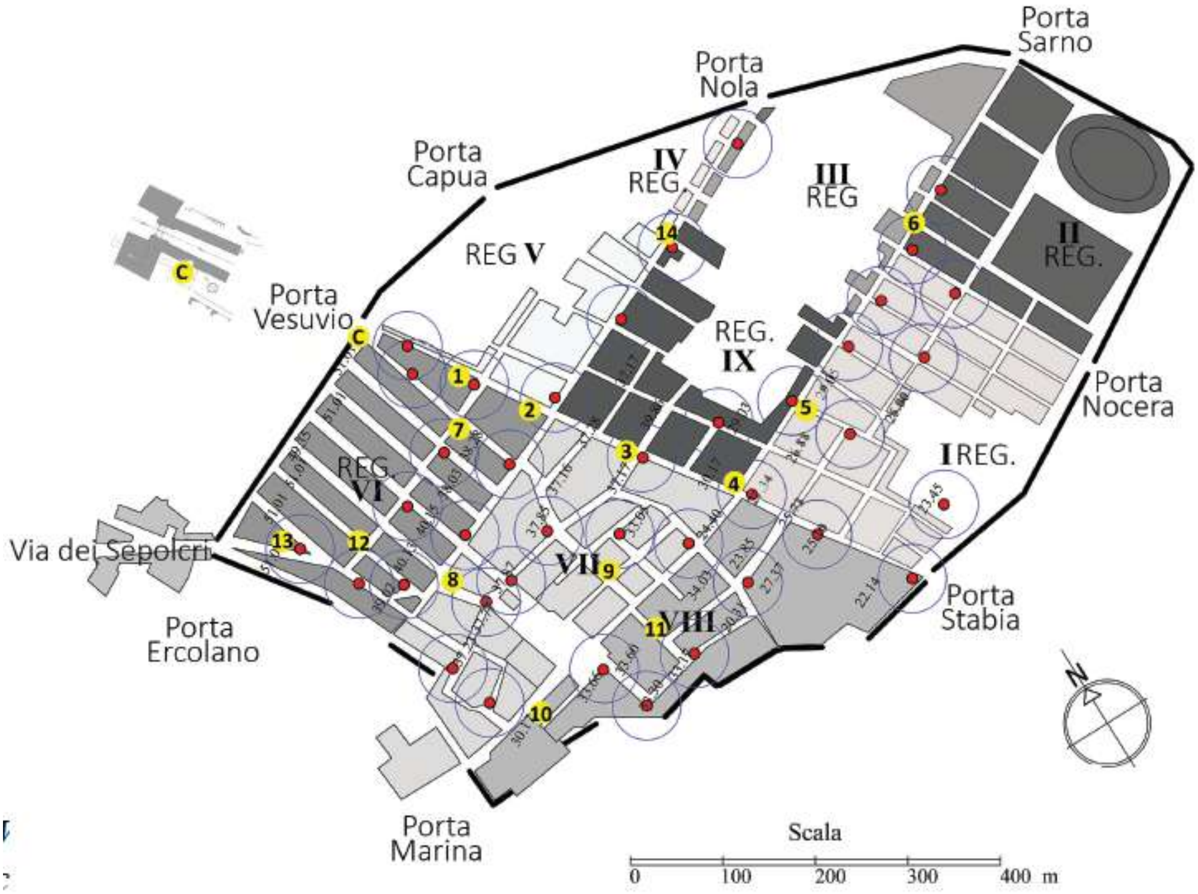

Figure10b. *Woter Tawers: city plan of Pompeii subdivided by region (height of the land shown in shades of grey) after Escherbach. Localization of turrets (1-17 yellow circles) and public fountains with drinking water (1- 42 red dots).*

Meet very specific requirements. Historically they are the most ancient of the known Roman baths, dating to the II century B.C. The baths were divided into two sections, one for men and the other for women extending over a surface area of more than 3500 sqm, including a wide courtyard with porticoes along three sides, used as a gym. A large pool was later added with dressing rooms and other services, sufficiently large for physical exercise in a covered area. To better specify the technical aspects of these systems, we note first the enormous requirement for water: for his thermal baths Agrippa, the founder of the Roman navy, had a special aqueduct built called the Aqueduct of the Virgin, that brought approximately 100,000 cm of water a day from Marino to the heights of the Pincio. Before it could be used, the water was collected in a colossal cistern that probably stabilised the quantity and pressure of the flow. Starting from the cisterns, a detailed distribution network formed of lead or terracotta pipes brought the water into the cold bath tanks and into the swimming pool, while the water to be heated was conveyed to the oven area, where it then went into the warm bath tanks by means of pipes and shunts issuing from the boilers. The oven (hipocausis) (hipocausis)[31], 28which in the first balnea was often located underneath the only heated room, was located in the central part of the building used for baths. The usual fuel was wood, stored in special sites in a quantity sufficient to last up to a month. The boilers used to heat the water were usually of bronze, or bronze in the lower section, which was directly touched by the flames and of lead sheets for the upper section. They were usually placed in a «jacket» of masonry to ensure stability and to limit the dispersion of heat. The battery system was very common, using two or three boilers in which the water was heated at different temperatures. These boilers were connected by pipes equipped with faucets, so that as the warmest water from the first boiler was supplied, it was replaced by the tepid water of the nearby boiler with great saving of time and fuel.

One way to prevent water from cooling inside the tanks or to maintain a constant temperature, described by Vitruvius, was the testudo alvei (literally «affixing of plates to the tank»): a bronze, semi-cylindrical container, in the shape of a testude or tortoise. This was heated externally, directly by the oven and placed on the bottom of the tank with the convex part directed upward, so that heat was conveyed to the water in a continuous and uniform manner. Whether warm or cold, the pools were fed by running water, since at thetime there was no way to purify water as we do now using filters and pumps. This meant a conspicuous discharge of water to the exterior of the baths that was used for various purposes, according to its temperature. In one case, it appears that it was even used to operate a mill, a confirmation of the logical nature of these systems, intended to minimise any loss and waste.

As for heating rooms, this was done by a system of air circulation as described above, using the hot air produced by the boiler.

Figure11. *City plan of Pompeii subdivided by region. Houses connected to the water-supply system. Houses in black and water towers in red from H. Eschebach.*

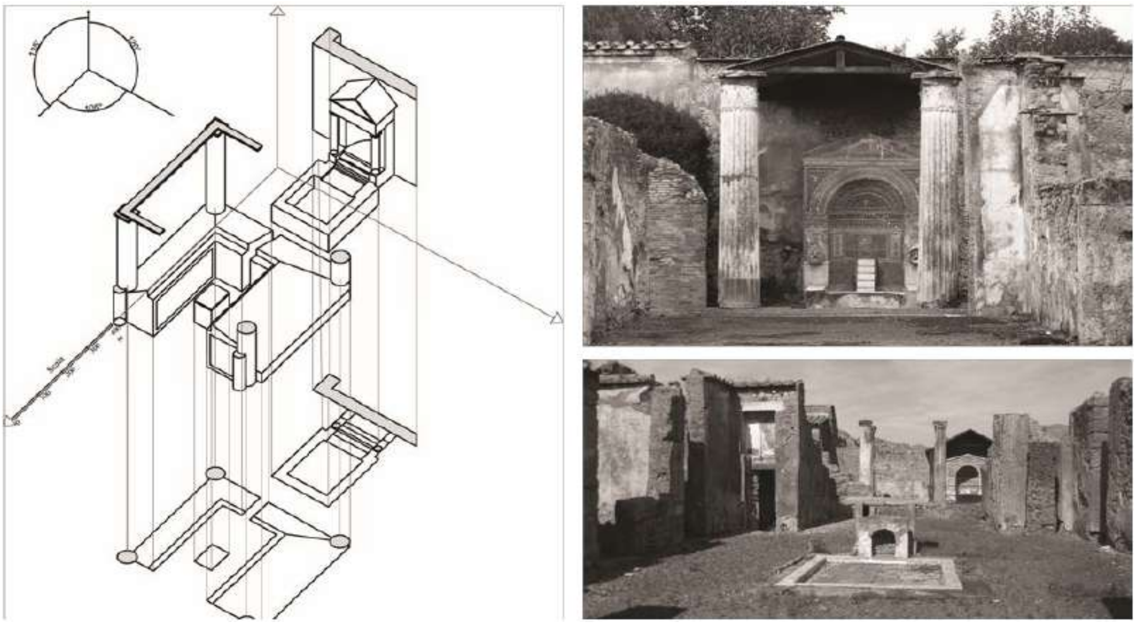

Figure12. *Atriums and peristyles of private dwellings.*

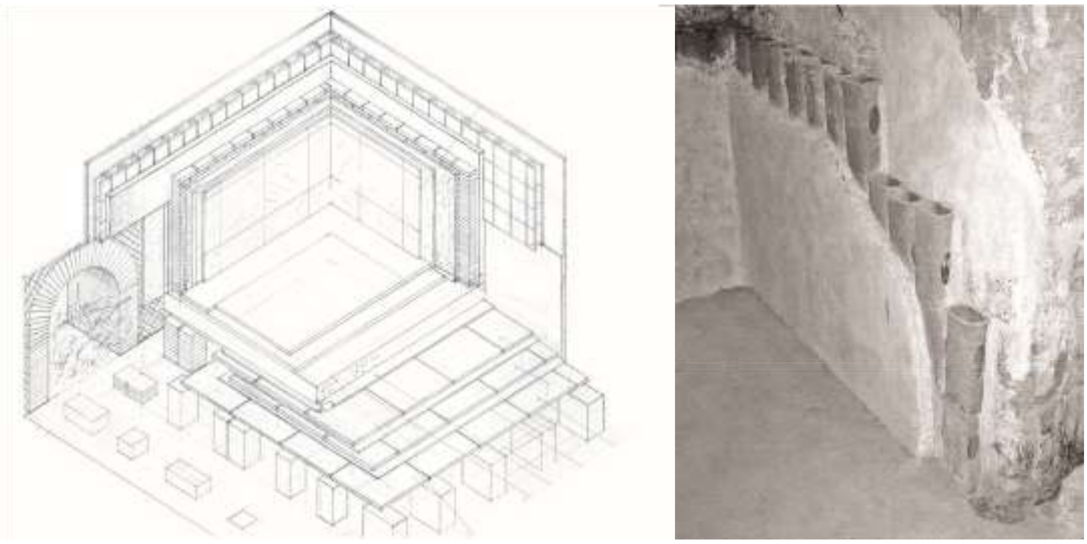

Figure13°. *Heating system, with small brick columns underneath the pavement and walled tubules: graphic scheme and terracotta pipes of sizeable width with joints still in place.*

Figure13b. *Internal caledarium bathroom.*

Figure 14a *Section of lead pipes found in Pompeii. They were made in segments of approximately 3 meters, or 10 feet, and have numerous weldings.*

Figure14b. *On the upper part of the pipes are signs of the longitudinal welding, the result of the process for curving a metal plate rather than drawing.*

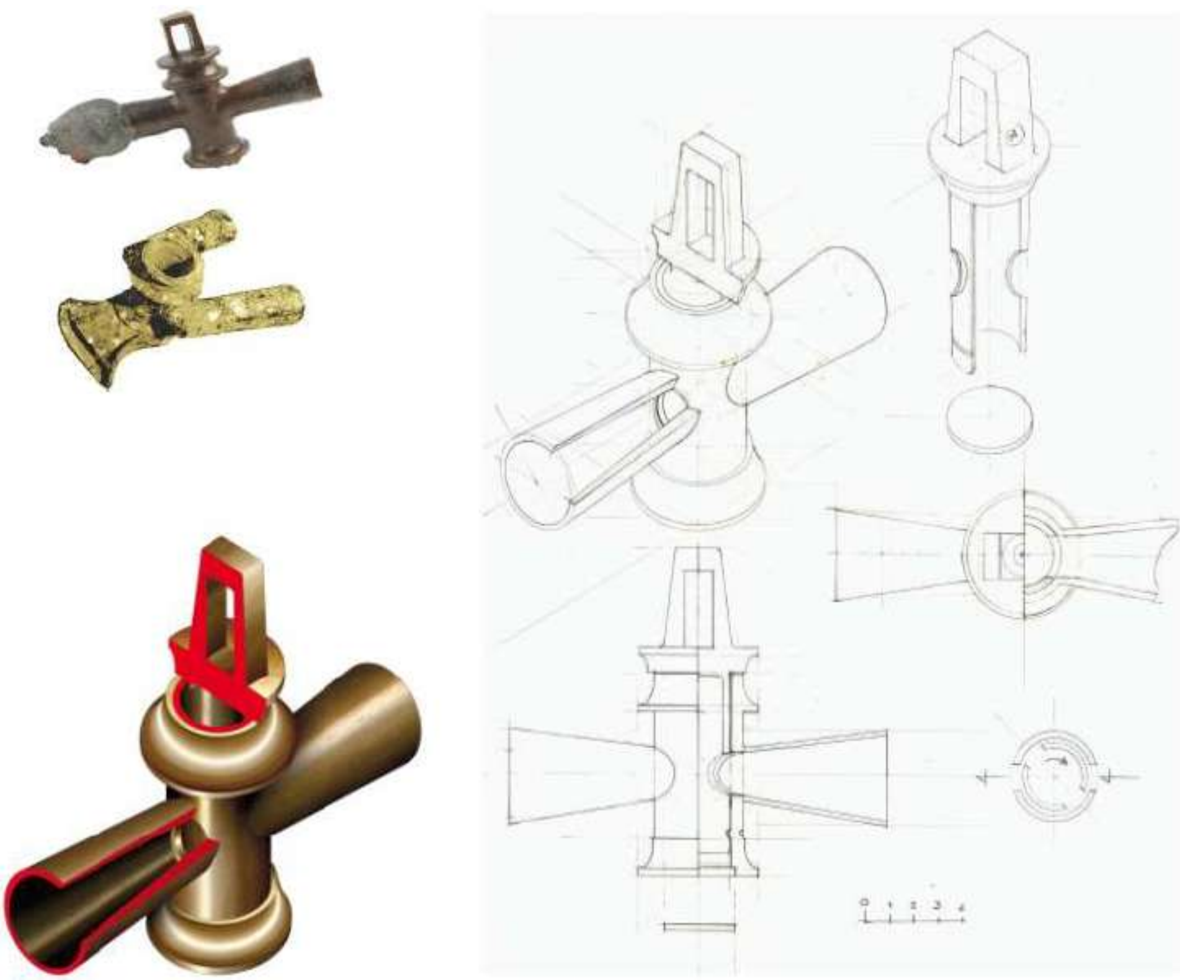

Figure15. *Bronze arrest valves found in Herculaneum and still functional. Drawing illustrating of the valve*

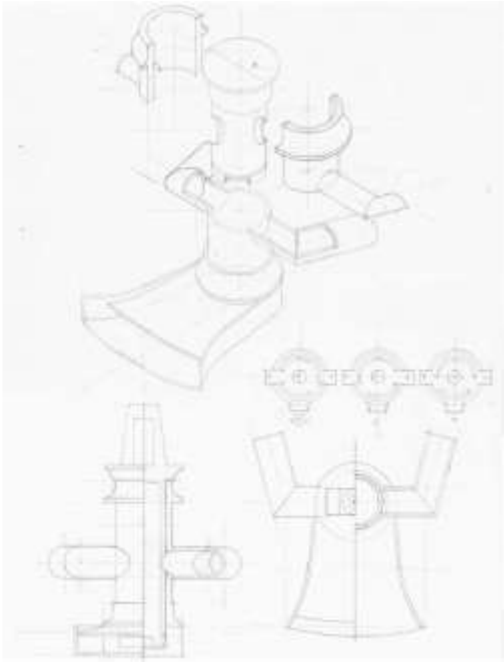

Figure16a. *Drawing illustrating operation of the mixer*.

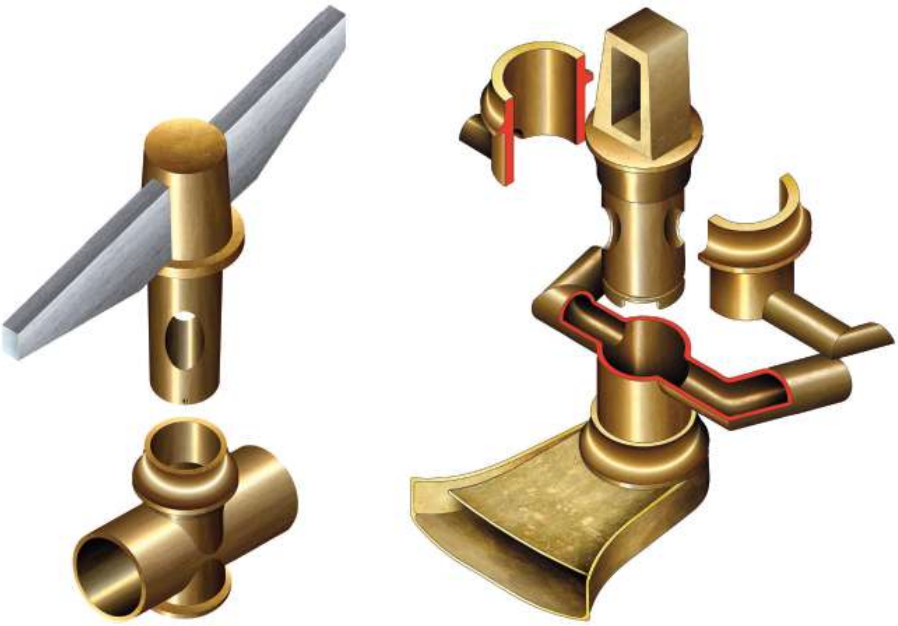

Figure16b

CONCLUSIONS

Pompeii was connected to the great Serino aqueduct under the rule of Augustus. Henceforth, water would no longer be just a precious resource but also a social status indicator. It is not by mere coincidence that the grandest homes were situated in "Regio VI", the quarter closest to the water reservoir (castellum acquae in Latin) with the greatest number of water towers and the first of the distribution network, which ensured that the peristylium fountains would never be left dry. The correlation between the configuration of the urban neighborhoods and the evolution of the waterworks network is based on the key factor of water availability in terms of easy access and continuous flow. The characteristics of the water distribution system such as conduits size, materials, maintenance requirements and accessibility show how drinking water was available to all but its distribution flow was less likely to be interrupted especiallywhere water was also required for other purposes like feeding the decorative fountains which were found in the homes of the upper classes as a mark of their wealth. The real estate price system whereby a greater distance from the cisterns and the water towers determined lower prices of dwellings was a main contributing factor to the urban socio- economic configuration and to the architectural character of the quarters. The authors' stance on the issue supports the hypothesis of Pompeii's water tri-partitioning device: the three main branches of distribution served three different urban areas rather than three different types of users private, thermal baths, public fountains and private residences). In this perspective the reflections of the authors' 2009 paper pertaining to the cascade water towers confirm that it was not the Roman engineers' response to users' demand for water that determined social class distribution and architectural character of the quarters47 but rather the choice of the upper class consumer to settle where water was more readily available.

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1 Cassio 1757; Fontana 1696; Lanciani 1881.

2 Maiuri 1973, pp. 15-41.

3 Todisco 2011.

4 «Sed ut salubrem magis quam ambitiosum principem scires, querentem de inopia et caritate vini populum servissima coercuit voce: satis provisum a genero suo Agrippa perductis pluribus aquis, ne homines sitirent». [Suetonius 71-75, De vita Cesearum,II, 42.]

5 Taylor 2012, pp. 34-40. Scattered springs would require several branch conduits feeding into a main channel ome systems drew water from purpose-built, dammed reservoirs.

6 Had to collect rain water, get it from the underlying Sarno river, or extract it from the 30 m deep wells, which were about 5 in total (Maiuri 1931).

7 Mays 2010, pp. 115-116.

8 Miccio 1994, p.9.

9 Adam 1984, p.89.

10 Ruocco 1976, p.153-154. Punctuated by 48 cruciform pillars, 4 rows long 70m, 25 wide and 15 deep in five naves it guaranteeda 12.000 m3 of water.

11 Adam et Varène 2008, p.85. [Il est très aventureux de s'avancer plus précisément et de se livrer à une estimation chiffrée du débit de ces trois canalisations, soumises au débit du diverticule de l'aqueduc et dans l'ignorance où nous sommes de l'existence ou non d'une distribution sélective de l'eau. Enfin, en ce qui concerne l'alimentation de la ville, on ne saurait rejeter a priori 48, si problématique soit-elle, la supposition de l'existence d'un second château d'eau, distribuant les quartiers Est et réduisant d'autant la répartition incombant au castellum de la porte du Vésuve].

12 Ashby 1935.

13 The castellum aquae of Pompeii; an architectural study. The Pompeii water tower found in 1902 was built at the highest point of the town, attached to the West side of the Vesuvius Gate. Water from one branch of the Serino aqueduct was collected in the water basin. The Aqueduct, with the tower, date to the Augustan period.

14 [Adam-Varène 2008, pp.37-72].

15 Vitruvius, VIII, 7.

16 [http://www.pompeiiinpictures.com/pompeiiinpictures/Plans/Plan%20Fountains.htm]

17 If a shut-off valve were closed, the lead conduit that fed the public and private fountains would have had to sustain a pressure of 5 kg/sqc, a quantity that exceeded the pipes' resistance. This serious limitation, insurmountable for the technology of the era, made it necessary to have pressure limiters, or piezometric turrets, an average of six meters high.

18 Zanker 1998, pp.120.

19 [http://www.pompeiiinpictures.com/pompeiiinpictures/Plans/Plan%20Fountains.htm]

20 Staccioli 2002.

21 The Swedish Pompeii Project has conducted archaeological investigations in insula VI and presented among other things the water distributionsystems inside the three houses (Ossel 2015: 74-79).

22 Borghi 1997, p.43.

23 Jashemski 1993.

24 Fagan 1999.

25 Vitruvius, VIII, 6.1.
26 Frontinus, lib. II, 105 [Baldassarre Orsini 1805].
27 Adam et Varène 2008, pp.280-283.
28 Maiuri 1931, pp.555, 562.
29 Presented a reconstruction of the urban water-supply infrastructure in the city. [Crouch 1993, pp.177-18; Eschebach 1979 (1977, 1983); Schmölder-Veit 2009].
30 Furnari 1994, n.XXIV Graphic Tables bent. Graphic scale 1:500 level curves.
31 Bruun 2003.
32 Ohlig 2014 (2001, 2002).
33 Hodge et Trevor 2002, pp.24–30, pp. 2, 17, 38, 98.
34 Fassitelli 1972.
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