Urban planning and water management in Ancient Aetolian Makyneia, Western Greece

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ABSTRACT

The findings of a large – scale archaeological investigation, conducted from 2009 to 2013 at a site in the vicinity of Antirrion – Western Greece, identified with ancient Makyneia, provides interesting information on the architectural features and urban planning of an ancient settlement in this area of mainland Western Greece. Through an interdisciplinary study of its morphological and technological characteristics water management problems and solutions can be revealed by the water management infrastructure (waterways, water reservoirs drainage systems etc.) as it has been documented during the excavation, An interesting question to investigate is whether water management systems of the ancient settlement represent sustainable techniques and principles that can still be used today. To this aim the functioning of systems is reconstructed and characteristic quantities are calculated both for the potable water system and the drainage system.

Key words | aetolian cities, ancient urban planning, drainage systems, historic buildings, hydraulic models, Makyneia, water management systems

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INTRODUCTION – GENERAL OUTLINE[1]

A large-scale archaeological investigation was conducted between 2009 and 2013 at a site known as 'Rizo' situated 1,100 m to the South-East of an acropolis called 'Palaiokastro' in the vicinity of Antirrion, Western Greece (Figure 1). Part of an ancient settlement was revealed on during the construction works of the 'Ionian Road'.

The excavation (Figure 2) turned out to be one of the most extensively involving habitation sites in the region of Aetolia and brought to light thirty-one buildings of different chronological phases and of varying degrees of preservation; additionally, the excavation revealed significant evidence with regard to the urban planning of the settlement (Saranti 2015).

This site has been identified as the site of ancient Makyneia, an originally Lokrian, but subsequently Aetolian city (Woodhouse 1897, pp. 326–331; Lerat 1952, pp. 189–191; Kolonas 1994; Freitag *et al.* 2004, pp. 379–390). The section of the city that was excavated extended to some 4,190 m^2 in an area overall measuring 32,000 m^2 on the south slope of 'Kokoretsa' hillock (altitude 253 m) and delimited by two water streams to the east and west. There were indications that it also extended at least northward, but the excavation was limited to the area of the roadworks under construction.

The settlement spans from the Late Geometric/Early Archaic period (7^{th}-6^{th} centuries BC) until the late Hellenistic

[1]The photographs and the site plan of the settlement are provided by the archive of the Ephorate of Antiquities of Aetolia-Acarnania and Lefkada with the kind permission of the director of the Ephorate, Dr O. Vikatou (© Hellenic Ministry of Culture and Sports, Ephorate of Antiquities of Aetolia-Acarnania and Lefkada).

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Q16 **Figure 1** | Map of the overall area, indicating the position of Ancient Makyneia.

period (2nd century BC). In its eastern sector some few prehistoric remains of buildings came to light, dating to the Early and Middle Bronze Age (end of the 3rd – first half of the 2nd millennium BC). Throughout the life – span of the settlement an irregular urban plan was maintained (Figure 3). This was probably due to its location on a hill slope, although it is possible that a more regular plan could have been applied in other areas, that stood on flatter ground, in accordance to other Aetolian cities, where the so-called 'Hippodamian' grid-plan had been partially used.

The settlement of Makyneia, and at least its excavated Hellenistic section, was nonetheless built in clusters or building units, extending across overlaying terraces and looking south, i.e. following the known principle as optimal orientation. All buildings appear to have been private houses. Among these, a monumental tower was discovered at the eastern edge of the settlement (Figure 4), a structure which, apart from its other potential uses, was probably overlooking a passage North-South to East-West directions, whereas the retaining walls and enclosure walls followed a more random direction depending on ground formation. Due to the natural southbound inclination, buildings had their narrow or, rather, their wider side turned to this direction. House entrances were most likely situated on the sides of the houses, mainly to the east and rarely to the south.

It is unfortunate that due to the hill's inclination and the damaging effects of modern cultivation, many of the buildings are missing their south side and their architectural plans are thus incomplete. The buildings remained plain and simple during their whole life duration, and their general picture is matching that of Athenian houses of the Classical period, as well as the available documentation of houses in north-western Greece. No specific

Figure 2 | Aerial photo of the excavated area at Rizo–Makyneia, in Aetolia, Western Greece.

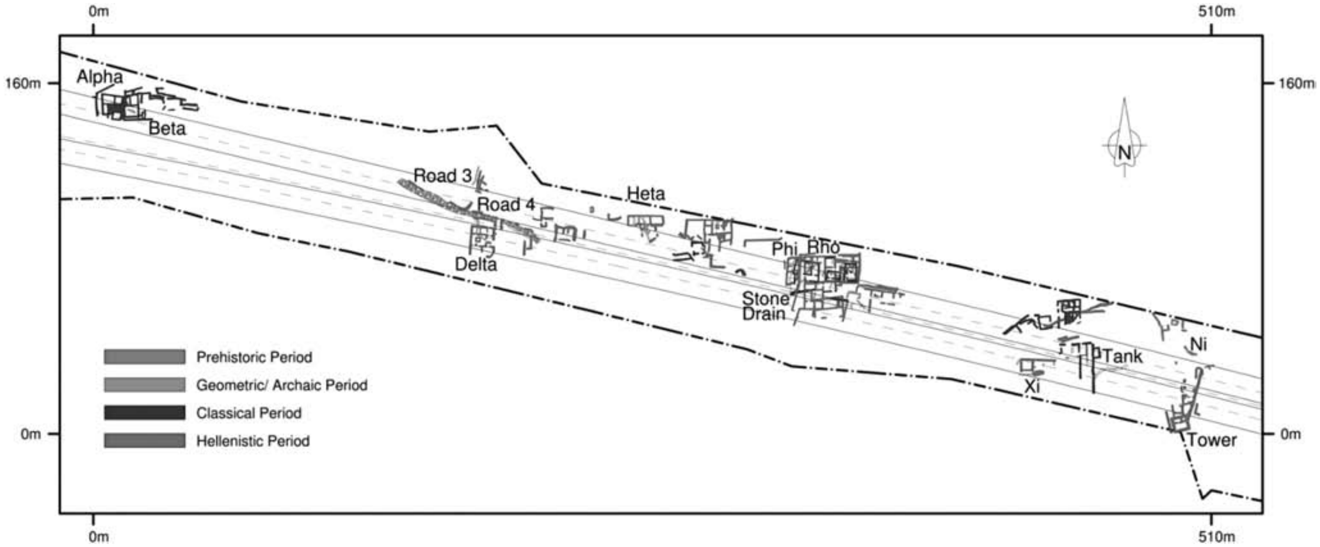

Figure 3 | Site plan of the settlement with its various chronological phases in different colours and the buildings mentioned in the article indicated by their names. Q17

Figure 4 | The remains of the Tower (Early Hellenistic Period) at the east side of the settlement.

Figure 5 | Building Delta.

house type is adopted. At least two of the excavated buildings, Building Delta (Figure 5) and Building Ypsilon (Figure 6) appear to have possessed an upper floor, whereas the tower was also a multistory building (Young 1956). During the Classical and the Hellenistic periods buildings were defined by enclosures which flanked them at three sides. This most probably occurred as a means of protection against landslides from the hill, that are principally occurring during winter, due to heavy rainfall; the results of such a phenomenon were detected among the northern houses.

The majority of the excavated buildings extended horizontally, whereas in the central sector of the complex, the structures have been extensively re-built over many periods. Owing to the favorable ground formation there was a well preserved succession of 3–4 different building phases. Therefore, houses of the Hellenistic period were built over houses of the Classical period, and they, in turn, had been built over houses of the late Geometric/early Archaic period (Figure 7).

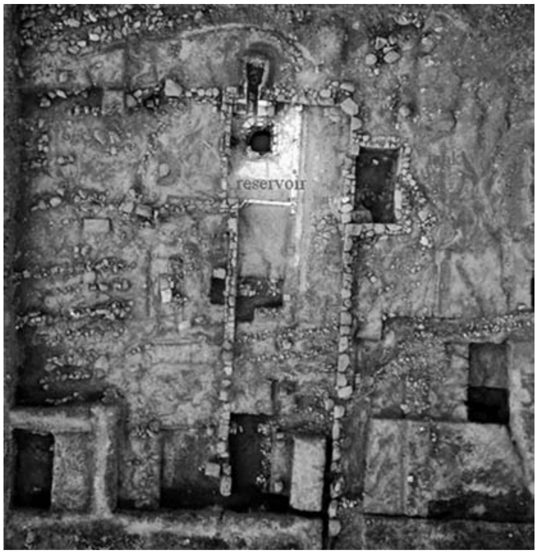

Figure 6 | Building Ypsilon.

Buildings were constructed with roughly worked stones of local, brittle sandstone, while in certain instances rock boulders have been incorporated in the construction. This practice primarily was occurring during the Hellenistic phase, when roof tile fragments were also plugged into walls. By contrast, walls of earlier phases were more diligently built and compact. Wall height preservation reached a maximum of 1.80 m. During the later phase of the Hellenistic settlement sizeable clay bricks were used in an ancillary way, as is also the general practice in other settlements in the Northwestern region of Greece (Hoepfner & Schwandner 1994, pp. 161). Layers of burnt bricks have been discovered in at least one building, whereas the roofs appear to have been made of Laconian – type tiles. Thresholds, columns and the overall structural elements of the houses were hardly elaborate and we assume that they were mostly made of wood; no limestone decoration or colored surfaces were traced.

EVIDENCE OF WATER MANAGEMENT IN THE SETTLEMENT

From the above general and short presentation of excavation data it is hopefully obvious that the topic of this presentation is a settlement without any exclusive features or architectural innovations, one that made use of elementary principles of urban and architectural planning in the different periods of its existence, but also in accordance to the features attested in other settlements in the wider region (Hoepfner & Schwandner 1994, pp. 158–161). The presence of two water streams at its eastern and western edges, as well as the short distance of the south side of the settlement to the sea (nearly 600 m), rendered the location ideal for the installation of a habitation nucleus.

The present paper includes a number of selected, characteristic examples of water management structures and implements from the site of Makyneia, which will serve here as a case study for water management problems in Western Greece during the historical periods previously specified. As has been already suggested the town plan

Figure 7 | The central area of the settlement with various phases/layers of the buildings.

was to a large extent dependent on its position on the southern slope of a hill. For this reason it has been necessary to take measures against eventual landslides coming down during the winter on account of heavy rainfall, by reinforcing the northern walls of buildings with retaining constructions. To this day, during the winter rainfall small waterways are created between buildings, while water makes its way downhill. Therefore, ground morphology and waterways, as it has been documented during the excavation, must not have been very different in ancient times. Apart from this a number of other structures relating to water management, both drinking and waste-water, has been discovered. These are mainly internal and external drains, water reservoirs, water wells and irrigation wells.

Therefore, starting with the drains, the instances of buildings Delta, Heta and Ro that date to the Hellenistic period will be described; drain systems were discovered in these buildings, relating to the use of certain rooms, or, more generally, to the use and water management in their interior.

Building Delta was one of the largest buildings, extending immediately south and under the level of a central street of the city. Under its walls an extensive drainage system was revealed; the system had taken advantage of the natural ground inclination to direct water away towards the exterior of the building to the East through its side entrance (Figure 8).

The drains in various rooms of Building Delta were constructed with vertically placed slabs and were covered either by roof tile fragments or by more roughly worked slabs; they were preserved in relatively good condition. They exhibited varying lengths, with the longest one measuring 15.15 m, whereas their width was usually 0.30–0.45 m. They were relatively shallow and therefore they were meant to carry away small quantities of water. It is suggested here that they could have drained rainwater from the road on the north side of the building inside Building Delta through its north wall.

Building Heta (Figure 9) presented a similar picture. A simple drainage system was discovered under rooms B1, B2 and C. In this instance also the drains had been constructed with small stones and the occasional insertion of roof tile and large ceramic containers (pithoi) fragments. They had been covered with medium-sized slabs, but in a few instances also with rectangular bricks. Their exact use is not understood. However it is possible that they were

Figure 8 | The drainage system of Building Delta.

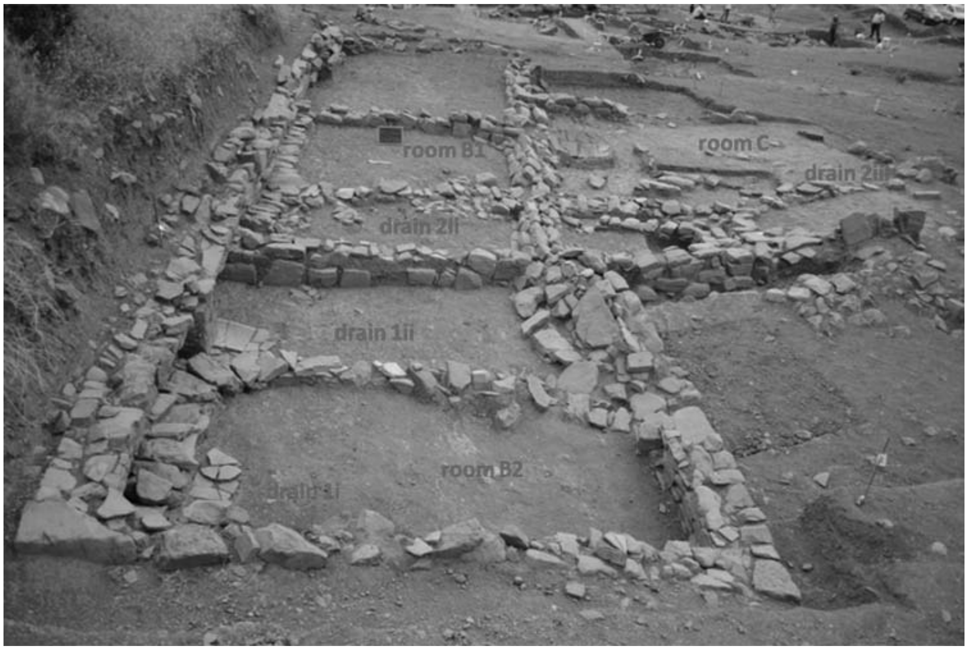

Figure 9 | Building Heta, with part of the drainage system discovered under the pavement of the rooms.

Figure 10 | The drainage system of Building Rho in rooms 4 and 5.

part of an organized drainage system that serviced some rooms and removed waste waters towards the exterior to the south by exploiting the ground's natural inclination.

Lastly, a drainage system preserved in excellent condition, was revealed in Building Rho, below rooms 4 and 5 (Figure 10). No further clues as to its exact function are available. The drains had a north-south direction, whereas in their final section they took a turn towards south-west and joined one another; then, they were jointly directed towards the exterior of the building through its entrance to the south.

Figure 11 | Aerial photo of the stone drain.

Figure 12 | The reservoir at the north part of the drain.

At the building's west side, where the drains from its interior all ended up, a sizeable, stone drain covered by slabs came to light (Figure 11), most likely used for the drainage of rainwater from the nearby hillock. It was an extraordinary find, since it demonstrates communal planning in its conception and construction. It was located between two buildings, Building Rho to the east and Building Phi to the west running through a narrow alley, in the manner well – known from ancient Olynthus. Its preserved length reached 27 m and had a sharp southbound inclination. Its walls were constructed from worked, medium-sized stones, whereas its northern end of 14 m long was covered by 24 slabs. This northern part of the drain was 0.94 m deep and 0.50 m wide. On the other hand, its southern part measuring 13 m was found open. The bottom of the drain was covered throughout with stone slabs.

A poorly preserved structure was detected in the drain's north end, one which could have served as a reservoir or settling basin (Figure 12) to receive running water coming down from the nearby hillock. It is due to its poor state of preservation that the interpretation is tentative. There was no structure, however, at the south end, and the water probably run through freely.

Three wells were discovered in the excavated part of the settlement, all located in its eastern sector and dating to different periods, as indicated by the buildings to which they were connected: two of these date to the Hellenistic period and one to its preceding Classical. They were all stone – lined, well-built and well-preserved, it is not however certain whether they were wells, i.e. if they were constructed around natural water sources in antiquity, or if they functioned as cisterns for collecting rainwater.

The first well, dating to the Hellenistic period, was situated on the north-west side of the Tower (Figure 4) and most likely serviced the needs of the building's residents. In order to facilitate smooth water drainage towards the interior of the well, the area around its opening had been covered with a water-impermeable floor, constructed from small pebbles and reinforced through coarse, hydraulic lime mortar.

Only a few segments of the mortar floor were preserved. The floor was inclined towards the well opening. The limit of the pebbled floor was set through roof tile fragments laid horizontally and covered by mortar, as the few preserved sections demonstrated. The well's opening was constructed of stones, and also its interior was dressed with local sandstone. It had a diameter of 0.60 m and its excavation reached a depth of 2.90 m. North-east of the well, a bathing installation was uncovered in a courtyard, as is the case in Delos, Leukas and Komboti in Akarnania (Saranti 2015).

A second well (Figure 13), also dating to the Hellenistic period, was detected in the area between Buildings Ni and Xi. It was less elaborate, had a stone opening and dressed walls and a diameter of 0.80 m and it was excavated to a depth of 4.50 m.

Figure 13 | The second well.

Figure 14 | The well next to Building Ypsilon.

The last well, dating to the Classical period (end of the 6th – beginning of the 5th century BC), was discovered in the northern sector of building Ypsilon and may be connected to this household (Figure 14). The area around its mouth was covered by a floor made of small, white pebbles; this pebbled floor had, in its turn, been covered with white, coarse lime mortar, which, in this case, was well-preserved. The mouth was constructed with medium – and large-sized stones and mortar. Its interior was dressed with local sandstone. Circular post-holes were discovered to the east of the well, and this element urges us to consider the area as partially roofed, probably as a means of protection for the well. The opening of the well was 1.37 m, but the excavation did not reveal its full depth.

An over ground water reservoir made of ashlars, rectangular stones, measuring $3.60 \times 2.00 \times 2.50$ m, was discovered on the south-east side of the well and had a maximum capacity of about 28.8 m^3 (Figures 6 and 15). The slab joints in the interior of the reservoir were covered by partially preserved hydraulic mortar for optimal insulation. Access to the reservoir, in all probability for maintenance and cleaning reasons, was facilitated through a permanent stone staircase made of five steps, located in its south-west corner. Judging by the layer of collapsed roof tiles that was found inside the reservoir, it is most likely that it was protected by a tiled roof and that this water tank served as a collector of rainwater through the roof. At the east side the opening was probably shaped in order to facilitate water overflows.

The reservoir was connected to buildings and constructions that date to the 5th century BC. Nonetheless, there is nothing to exclude its use also during the Hellenistic period, when the settlement grew bigger and the water supply needs also increased. In fact, it is probably not accidental that two pottery kilns of this period were located nearby, since water was absolutely necessary in making pottery.

The sector of the settlement with three wells, the reservoir and a notable number of internal and external drains overlaid a water stream called 'Haloul-Aga', one which continues to flow until this day. It has abundant water even in the summer and forms small waterfalls in the winter further north. A modern watermill, nowadays abandoned, lied at a short distance to the northeast of the site of the ancient settlement. The position of the Tower in the same sector cannot be irrelevant to the water stream, which, already since the Early Hellenistic period, was a reference point for the site's inhabitants. In the Classical period this sector speaks for central planning and organization by a larger group of people other than that at a household level.

At the western edge of the excavated section of the settlement the second water stream ('Nyforema'), a considerably smaller one than its eastern counterpart, can be found, also flowing until this day. Through a path running along its eastern bank, there was easy access to the acropolis of the city (Saranti 2013). In this sector of the settlement, buildings of the Classical period were uncovered.

GEOLOGICAL AND SOIL CHARACTERISTICS OF THE SETTLEMENT

From a geological perspective, the area of Makyneia belongs to the zone of 'Gavrovo – Tripolis', which is inserted between the Miocene Ionian zone and the zone of 'Olonos-Pindos'. It is characterized by large scale displays of flysch and carbonate parts. These appear northwards, on Mount Makrynoros and southwards, on the hills of Klokova and Varasova, The Upper Cretaceous limestones constitute the lower display area of this zone and consist of light ash and yellowish color layered limestone that become locally dolomitic. Their thickness is of a few hundred meters.

The Eocene limestone is platy limestone with a very limited display (Laboratory of Environmental Geology of the
Q2 University of Patras 2014).

According to a geological map of the area (Lekkas 1997), the region is situated marginally between formations of side scree and cones of scree (water permeable formations of very low permeability) and flysch (semi-permeable formations of low permeability).

HYDRAULIC CALCULATIONS

In 'Appendix 1' hydraulic calculations are given in order to estimate the quantity of rainwater that was in inflow into the town and whether this quantity could be drained by the central stone drain.

From the hydraulic calculations it has been derived that during an extreme flow (with a return period more than 250 years) flood, the stone drain could not be efficient enough to drain the rainwater from the upwards hill.

It is known that there is an extended drainage system around the houses and that there are dispersed wells (Figures 4, 13 and 14) and one water reservoir (Figure 15), all situated in the 'connective tissue' of the town. A critical reflection can be stated that these constructions were made for the protection of the city and relief from the flood runoff, since: (a) the town is bordered by two streams (westwards and eastwards) and (b) it seems like there was initially a wrong design in the construction of the main sewage of the town.

Thus, obviously, various corrective interventions had been made firstly to protect the town and secondly, to recharge the aquifer (wells and reservoir, due to lack of wells or other pipeline downwards of the city), in order the water could be pumped in arid days for various uses.

From the calculations in 'Appendix 2', it has been revealed that these water wells and reservoirs infrastructures would be sufficient for less than 50 inhabitants who lived in this area. It can be assumed that the water supply of the city might be satisfied with the use of additional water sources, such as springs and the two small rivers.

All in all, this calculated carrying capacity would have effect, only if there was a feedback of the reservoir and the wells from a steady water fountain.

Figure 15 | The water reservoir at the east part of Building Ypsilon.

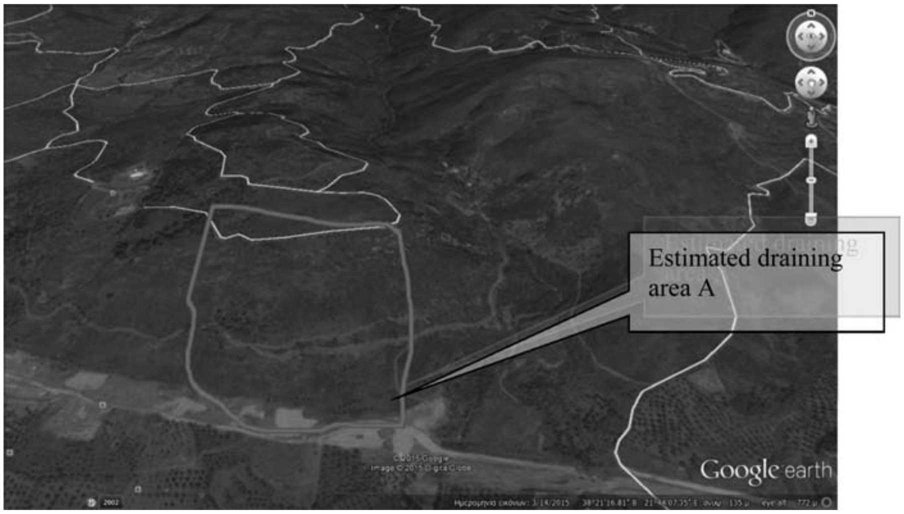

Figure 16 | Estimated draining area. Q15

This has not become clear of the archeological findings, thus, a critical statement can be claimed that the reservoir, along with the other wells, played the role of water reserve for the arid days or even worse, for the difficult days of warfare, when, for instance, the town was under siege.

The low water permeability properties that have the region, as it has been mentioned here above in section C, limit the infiltration of rainwater and thus, the recharging of the aquifer is not easy.

This fact might be an explanation to the already mentioned presence of many structures such as reservoir, wells, etc., since a soil of low permeability acts as a geological barrier. This barrier causes to the creation of an overhanging aquifer in the depth where the geological barrier is identified (Mylona & Xenidis 2010).

Therefore, it can be alleged that the many existing structures were acting as an overhanging aquifer, while with the free disposal of rainwater by the great stone drain was tended to make efforts in order to recharge the aquifer, despite the low water permeability.

Here it must be taken into account, that probably in the past, it might have existed larger annual amount of precipitation. As it concerns the period 1962–1993 in the vicinity of Nafpaktos, the annual amount of precipitation was about 830 mm (Mariolakos *et al.* 2001), while always the surrounding area of Western Greece has presented, until today, annual amount of precipitation comparatively larger than in the rest of Greece.

Nevertheless, the amount of precipitation should be generally estimated the same as today, if not more, as mentioned previously, since it may be reported as an informative element that in ancient Athens the annual amount of precipitation was 400 mm (Krasilnikoff 2013), quantity which is very close to the current average annual level.

CONCLUSIONS

From all that has been mentioned above, it is obvious that the town of Makyneia is an interesting example, from an interdisciplinary point of view, not only because of the successive phases represented in the residues, but also because of its spatial elements combined with its infrastructure projects, with particular emphasis on water storage system and the sewer system.

The evidence laid previously with regard to water management in the settlement of Makyneia shows clearly that the inhabitants were diligent and cautious on the matter and that the choice of the site was far from a random selection, but on the contrary one offering convenient access to water sources. Despite the relative simplicity which buildings exhibit, especially during the Hellenistic period, its water management system demonstrates characteristics of solid planning and communal organization, otherwise absent in other levels of community life, with the possible exception of road construction. The lack of more wells or reservoirs in the settlement, in contrast to other settlements in the region which had reservoirs in their courtyards, could be indicative of potable flowing water abundance and sustainability on account of the site's proximity to the two water streams. In any case it seems that the basic principle of water supply was to utilize all the available exploitable water resources with the least physical effort, according to the general manners of ancient Greek water management (Crouch 1993, pp. 312–317).

It is also evident that there was provision and care for the disposal of waste and storm waters through drainage channels inside the houses and in public areas, which could be possibly reused for irrigation purposes. On the other hand, clay pipelines are surprisingly completely lacking, a fact that shows that fresh drinking water was mainly provided from the wells or the two nearby streams. Additional water may have been supplied by large ceramic containers (pithoi) standing at courtyards and used as rain – water collectors in the manner well known from many ancient Greek cities.

Water management requirements obviously affected the architectural form of the houses, since a network of built channels following the natural ground inclination was in most cases necessary in order to lead rain and waste water away. Also cisterns and wells were adapted in houses plans and adjacent to places were water was mostly needed.

Considering the water storage system, it has been found that serious efforts had been made through the infrastructures, in order to ensure storage capacity of water, on a basis of a sustainable philosophy. As it concerns the sewer system, it can be alleged that due to the wrong initial design and estimation of the carrying capacity, a number of constructing operations had been made over the time, to render the whole system sustainable, since the idea of sustainability was diffused in the constructions of the ancient Greeks (Kollyropoulos *et al.* 2014, 2015).

REFERENCES

Chow, V. T. 1959 *Open-Channel Hydraulics.* McGraw-Hill, New York. Q3

Crouch, D. P. 1993 *Water Management in Ancient Greek Cities*, Oxford University Press, New York.

Freitag, K., Funke, P. & Moustakis, N. 2004 In: *An Inventory of Archaic and Classical Poleis, an Investigation Conducted by the Copenhagen Polis* (M.H. Hansen, ed.). Centre for the Danish National Research Foundation, Oxford. Q4

Gleick, P. H. 1996 Basic water requirements for human activities: meeting basic needs. *Water International* **21**, 83–92. Q5

Hoepfner, W. & Schwandner, E. L. 1994 *Haus und Stadt im klassischen Griechenland*. Wohnen in der klassischen Polis I, München.

Kollyropoulos, K., Antoniou, G., Kalavrouziotis, I. K. & Angelakis, A. N. 2014 Hydraulic characteristics of the drainage systems of ancient Hellenic and roman theatres: a preliminary study. In: *Proceedings of 'IWA Regional Symposium on Water, Wastewater and Environment: Traditions and Culture'. Patras, Greece.*

Kollyropoulos, K., Antoniou, G. P., Kalavrouziotis, I. K., Krasilnikoff, J. A., Koutsoyiannis, D. & Angelakis, A. N. 2015 Hydraulic characteristics of the drainage systems of ancient Hellenic theatres: a case study of the theatre of Dionysus and its implications. *Journal of Irrigation and Drainage Engineering (ASCE)*. doi:10.1061/(ASCE)IR.1943-4774.0000906.

Kolonas, L. 1994 *Makyneia Through Recent Archaeological Research*, in *Naupaktiaka 6 (1992/1993)*, pp. 79–95. Q6

Koutsoyiannis, D. 2001 Elaboration of studies for the section Antirrio – Kefalovriso of the West Highway N-S. Hydrological study area road Ionian Highway. In: *General Secretariat of Public Works, Ministry of Environment Country Planning and Public Works, Athens, Greece.* Q7

Koutsoyiannis, D. 2011 *Design of Urban Sewers*, 4th edn. NTUA, Athens, Greece. Q8

Krasilnikoff, J. A. 2013 Innovation in Ancient Greek agriculture: some remarks on climate and irrigation in classical Attica. *Classica et Mediaevalia* **64**, 95–116.

Laboratory of Environmental Geology of the University of Patras 2014 *Strategic Environmental Impact Assessment for the Exploration and Exploitation of Hydrocarbons in the Land Domain 'Etoloakarnania' of the Region of Western Greece.* Ministry of Environment Energy and Climate Change, Athens, Greece.

Lekkas, E. 1997 *Elaboration of Neotectonic Map of Greece. Aetolia and Acarnania County.* Prefecture of Aetolia and Acarnania, Messolonghi, Greece.

Lerat, L. 1952 Les Locriens de l'Ouest, I, 34, 82-84, 189-191, II, 61, 66, Paris, France.

Mamassis, N., Defteraios, P., Zarkadoulas, N. & Koutsoyiannis, D. 2015 *Research on Water Supply of Ancient Piraeus-Representation of Ancient Cisterns Operation*. Available from: https://www.itia.ntua.gr/getfile/1550/1/documents/Pres_cist_5_14_fin.pdf (accessed 28 December 2015). Q9

Mariolakos, H., Fountoulis, I. & Theocharis, D. 2001 Management of water supply and irrigation needs of the Prefecture of Aetolia and Akarnania using GIS. In: *Proceedings of the 9th Congress of the Geological Society of Greece, Bul. of Geological Society of Greece*, vol. XXXIV/5, pp. 1835–1842.

Mays, L. W., Sklivaniotis, M. & Angelakis, A. N. 2012 Water for human consumption through the history. In: *Evolution of*

Q10 *Water Supply Throughout Millennia* (A. Angelakis *et al.* eds).
Q11 IWA Publishing, London, UK, Ch. 2, pp.19–42.

Mylona, E. & Xenidis, A. 2010 Natural formation of geochemical barriers at the sulphidic tailings disposal areas. *Minerals Wealth* **156**, 19–34.

Saranti, F. 2013 Ancient Makyneia: recent exploration and conclusions. In: *Forthcoming in the Proceedings of the 2nd Archaeological and Historical Congress of Aetoloakarnania and Leukas. Messolonghi, Greece.*

Saranti, F. 2015 Finds during the construction of the south section of the 'Ionian Highway' (Antirrhion – Chalkeia). In: *Proceedings of the 4th Archaeological Meeting of Thessaly and Central Greece, 2009–2011, From Prehistory to the contemporary period (Volos 15–18/3 / 12)*, vol. II. *Volos, Greece*, pp. 621–632.

Saranti, F. & Georma, F. 2013 Architectural remains from ancient Makyneia: a first approach. In: *Forthcoming in the Proceedings of the 2nd Archaeological and Historical Congress of Aetoloakarnania and Leukas. Messolonghi, Greece.* Q12

Saranti, F. & Georma, F. 2014 Ancient Makyneia in Aetolia: the urban organization of a settlement through its architectural remains. In: *Forthcoming in the Proceedings of the Congress 'The Archaeological Activity and Research in North – West Greece and the Ionian islands'*. University of Ioannina, *Ioannina, Greece.* Q13

Woodhouse, W. J. 1897 *Aetolia, its Geography, Topography and Antiquities*. Oxford, pp. 326–331.

Young, J. 1956 Studies in south Attica: country estates at Sounion. *Hesperia* **25**, 122–146.

Zorn, J. R. 1994 Estimating the population size of Ancient settlements: methods, problems, solutions and a case study. *Bulletin of the American Schools of Oriental Research* **295**, 31–48. Q14

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