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Ancient Greek Water Management:
The Case of Northern Greece

Par

Shelby Vieira

Centre d’études classiques

Faculté des arts et des sciences

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Présenté par

Shelby Vieira

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Jacques Y. Perreault

Dimitra Malamidou

Christian Raschle

Résumé

L'eau est une ressource essentielle pour nourrir les hommes, les animaux, et les plantes. Par contre, les eaux stagnantes peuvent attirer vermine et maladies, et les fortes pluies provoquer des inondations soudaines. Malgré son caractère essentiel, l'archéologie de la gestion de l'eau dans le nord de la Grèce est souvent limitée à quelques paragraphes inscrit dans des études plus vastes, à l'exception de quelques articles comme « Sanitation and Wastewater and Stormwater Management in the Ancient Kingdom of Macedonia » de E. Kaiafa. Ainsi, ce mémoire a pour objectif d'examiner la manière dont les Grecs ont relevé le défi de l'approvisionnement de leurs villes en eau potable et de l'évacuation des eaux usées et impures, aux périodes archaïque, classique et hellénistique.

Ce mémoire s'articule en quatre chapitres afin de fournir une analyse descriptive détaillée des différentes facettes de la gestion de l'eau. Après une introduction générale, nous nous pencherons d'abord sur l'attitude des Grecs anciens envers l'eau et sur leur conception d'une source d'eau fraîche. S'ensuivront un survol des condition géographiques en Grèce du Nord ainsi qu'une discussion sur la manière dont celles-ci peuvent affecter l'étude des systèmes d'eau de la Grèce antique. Les trois autres chapitres se concentreront sur l'étude des vestiges et archives archéologiques de diverses villes du nord de la Grèce, comme Argilos, Pella, et Thasos. Premièrement, les structures artificielles construites pour récolter les sources d'eau douce seront étudiées. S'ensuivra un chapitre s'attardant à la question de la relation entre la gestion de l'eau, la topographie de la ville, et le drainage urbain et domestique. Finalement, une section portant sur l'évacuation des eaux dans les fortifications du nord de la Grèce conclura cette étude.

Mots-clefs: Archéologie, Grèce du Nord, archaïque, classique, hellénistique, gestion de l'eau, sources d'eau, drainage, urbanisme, études environnementales.

Abstract

Water is an essential resource for nourishing people, animals, and plants. At the same time, stagnant waters attract vermin and disease, and heavy rainfall causes flash floods. The archeology of water management in Northern Greece is often regulated to a few paragraphs in a broader context, except for articles such as E. Kaiafa's on "Sanitation and Wastewater and Stormwater Management in the Ancient Kingdom of Macedonia." This thesis explores how the Greeks handled the challenges of sustaining their cities with water and ridding themselves of used and impure waters in the Archaic, Classical and Hellenistic periods.

This dissertation is separated into four main chapters in order to provide a descriptive analysis of what pertains to water management. After a general introduction, the first topic of interest outlines the ancient Greek attitudes toward water and their view of a portable water source. To complement this, there is also a discussion on the geographical conditions of northern Greece and how that affects the study of ancient Greek water systems. The other three chapters study the archeological record from various cities all over northern Greece, such as Argilos, Pella, and Thasos. The first of those chapters discusses what manmade structures were constructed to harvest freshwater sources. Following this is a study on the connectivity of water management, the city's topography, and urban and domestic drainage. A section on the water evacuates found on northern Greek fortifications concludes the study.

Keywords: Archeology, Northern Greece, Archaic, Classical, Hellenistic, Water management, Water sources, Drainage, Urban planning, Environmental studies.

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List of abbreviations

ΑΕΜΘ	*Archaiologiko Ergo ste Makedonia kai Thrake*
Hist.	*Historia, Zeitschrift für alte Geschichte*
JIDE	*Journal of Irrigation and Drainage Engineering*
ΚΕΟΔΥ	*Κέντρο Ολοκληρωμένης Διαχείρισης Υδάτων*
Olynthus VIII	Robinson, David M., and Graham, J. Walter. 1938. *Excavations at Olynthus, Part VIII: The Hellenic House: A Study of the Houses Found at Olynthus with a Detailed Account of Those Excavated in 1931 and 1934*. Baltimore: Johns Hopkins Press.
ΠΑΕ	*Πρακτικά της εν Αθήναις Αρχαιολογικής Εταιρείας*

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1.0 Introduction

Water is an essential resource for the prosperity of civilizations. It quenches the thirst of all living creatures, provides nourishment to food resources, and ensures the survival of human society. On the other hand, water also attracts disease, vermin, and disaster thus becoming a liability. This duality is crucial when discussing water management in ancient Greek cities. Managing areas where thousands of people lived in conjunction with each other was difficult. The demand for a large amount of water to meet the needs of the urban population increased with the population, and eventually, they could no longer depend only on the natural world to provide them with nearby water sources. Thus, it demanded human intervention to facilitate fresh water acquisition and to protect the city's inhabitants from dirty water.

Because of how important water is, various scholars have studied the inner workings of water management with a focus on the more elaborate and evident features such as the Tunnel of Samos, the Peisistratid aqueduct, the great aqueducts of the Romans, or prominent sewage collectors such as the Great Drain in the Athenian Agora. These impressive structures are referenced by ancient authors for being remarkable accomplishments. However, few scholars focused on standard structures like the trajectory of drainage channels or how the city's topography aided in draining any water safely. The number of studies done on water systems inside the geographical area of Northern Greece is even less, where often the topic is reduced to a few sentences in favour of looking at the more impressive features of the elaborate water structures built by the Romans.

The basis of this project is the connection between Greek urban life and water management as well as how the Greeks developed structures to facilitate the urban acquisition, distribution, and disposal of water. The idea for this project arose from a reflection on water management at the site of ancient Argilos, where excavations revealed several buildings and an urban plan of great interest for the Archaic and Classical periods. This work will thus focus on ancient cities in Northern Greece during the Archaic, Classical, and Hellenistic periods. To further constrain the topic, the water systems that will be discussed are public and private water and drainage systems and will set aside any rural water features.

1.1 Historiography

Concerning water systems, only a few scholars have written extensively on them. Instead, the tendency is to publish articles on the topic, sometimes including them in books by several authors. Within the perimeters set for this study, even fewer sources have delved into water management in Northern Greece.

In terms of the general topic of water management, there are two primary works which have defined the terms of water management. First, Dora Crouch broadened her focus to look at water management all over Greece in her book on *Water Management in Greek Cities*, published in 1993. This book concentrates on the fundamental questions about water management. For example, how was fresh water acquired, which building used water, what was its disposal, and what was the connection between urbanism and water management. Since her research covers the totality of the Greek world, a wide range of cities were consulted, including those in Magna Graecia and Asia Minor. The second is a collection of articles in *The Handbook of Water Technology*, edited by Örjan Wikander. This work has eight sections with various articles written by different authors. Several articles discuss the discipline of water management in question, such as water supply, urban use, water as an aesthetic and water legislation, delving into more technical topics, like the structure of wells, or more literary topics, such as water legislation.[1] This book provided a clear and comprehensive way to identify each feature while surveying each city.

Regarding specific interests, Peter Klingborg published his dissertation on unpublished cisterns in ancient Greece between 600-50 BCE. His dissertation has various chapters, all delving into discussing cisterns. The first concerned itself with the inner workings of cisterns where he described what constitutes a cistern and what they looked like. The other part was a catalogue with all the cisterns not previously documented from various cities such as Athens, Delos, and, more importantly for this study research, the cisterns of Olynthus.

Within the study of water management, the preferred method to publish articles is to compile them into books for general and specific topics—for instance, the subject of three books, each edited by Berkins, Jonas. Mays Larry, and Mithen Steven, are water management in the

[1] For instance. Trevor Hodge's various studies on wells, cisterns, qanats, and aqueducts.

ancient world, but the coverage area is not solely Greece. Instead, there are discussions on water technology in the Roman world, Egypt, Mesopotamia, and the Americas. Another edited by Sandra Lucore and Monika Trümper organizes different articles on baths in the Greek world. The book provides a good understanding of the plan of Greek baths, which helped comprehend the identification of Greek over Roman baths while surveying the cities. These compilations of articles are rich in content, often delving into more specific content and bibliographical references for further research.

The water systems of Northern Greece have little coverage, with only two articles that cover the geographical region. Kaiafa, Papanikolaou, Melfos, Papachoralampou, and Voudouris collaborated on "Sanitation and Wastewater and Stormwater in the Ancient Kingdom of Macedonia" in the book *Evolution of Sanitation and Wastewater Technologies through the Centuries* from 2014. The article discusses how the ancient Macedonians dealt with amassing enough fresh water for the population and expelling the used water from these well-known cities. Similarly, Kaifa and Karadedos wrote an article called "Urban and Wastewater Systems in Ancient Macedonia" in 2013, which gives a general overview of the territory of ancient Macedonia, focusing on the more prominent sites in Northern Greece. These articles provide a in-depth description of which sites have extensive water systems.

Most of the other studies focus on a single attractive feature, such as how the article by Yannopolis and Kaiafa, S. "Evolution of Water Supply Infrastructures of Thessaloniki City, Hellas, through Centuries" from 2017 and the article by Manoledakis Manolis, "The water supply of Roman Thessaloniki" from 2018. Although the focus is not specifically on the water systems, various scholars have studied them in conjunction with their field of research. For example, Yves Grandjean delves into each outlet and inlet of water in Thasos in his study of *Les Rampart de Thasos* and the drainage systems in his account of the *Guide de Thasos*, published in 2011 and 2000. Similarly, Dr. Nicolas Cahill wrote a comprehensive study of the daily life of the population of Olynthus and the archeological evidence found during the excavations in the book *Household and City Organization of Olynthus* in 2002. This study includes information on the city's water supply and drainage features in and around the houses.

Finally, the Ministry of Culture in Greece published various touristic guides explaining the sites and their archeology history. These guides highlight the finds in the museum and provide a summary of the architectural elements within the archeological site. There are mentions of the water supply and drainage system regarding water management. Direct references to the water system could include mentions of large sewers or fountains but are few compared to the indirect references. These vague references are in other notable features, such as the agora or domestic houses, where water features tend to be. These references provided a vague understanding of what the water systems in each area could look like and an in-depth bibliography for future reading.

1.2 Methodology

The first and most crucial step of commencing this thesis was establishing a list of prospective archeological sites that were contemporary with the parameters of the topic. These sites were compiled by consulting modern studies of water features and the various sites that made up Northern Greece. One particularly helpful project was the *Itia* research team led by Nikos Mamassis, which compiled a website listing 128 hydraulic works from all over Greece and every period. These sources provided background information on each site and a brief idea of the conducted research regarding their water systems.

The final list of consulted sites includes Aigai, Amphipolis, Aphytis, Argilos, Dion, Kerdylion, Olynthus, Pella, Philippi, Stagira, and Thasos. Surveying the chosen sites provided the needed information to study the waterworks properly, such as the type, location, measurements, and nearby structures. The results provided the initial impression of the water features and allowed for identifying the kind of water feature and how large the construction project was. This information was coupled with further research into the cities and the surrounding districts to rebuild each city's water systems.

Further research on each establishment and the surrounding area supported the results collected from the surveys. It allowed for careful examination of the archeological remains of the water system, the buildings that need water, and the drainage arrangement, along with studying how the urban plan aided in understanding water management. Through the catalogue and research from other authors, it was possible to begin exploring vital water management topics:

how the ancient peoples retrieved their water, organized their city to access water regularly, and evacuated the used or greywater from the city to preserve a certain level of sanitation.

2.0 Obtaining Fresh Water

2.1 Ancient Attitudes

With water necessary to everyday life, it is not odd for the ancient peoples to highlight this importance in the sources that survive until today. The literary tradition is one such way to understand how the ancient Greeks thought and their attitudes concerning what water meant to them to complement the archeological record. While mythology has survived through the academic record, it was originally an oral tradition and provided insight into the rationale and attitudes passed down throughout the Greek tradition. Similarly, although clinical, legislation emphasizes the importance of regulating water and what that means for the population it governs. In both features, the shared attitudes towards water categorize it as either an aid or a hindrance.

Through the lens of mythology, it is possible to observe this duality. The mythological tradition passed down from generation to generation depicted water with a double standard. The personification of different bodies of water reflects these attitudes. Large bodies of water were deities with distinct personalities within myths. There are two types of mythological beings closely associated with water. The sons of Okeanus and Tethys are known as river gods, while nymphs were female water springs.[2] The presence of nymphs was often used as protectors of public waters such as wells, gushing springs, fountains, and other sources of water.[3] This can be seen at the site of Aphytis, where there is a nearby cave with evidence of ritual activity from the 10th and 9th centuries BCE dedicated to the Nymphs with a water spring inside. This spring provided the other parts of the sanctuaries with a fresh water source.[4] These waters provided a clean water source for the Greek population to use daily.

On the other hand, the river gods play a more prominent role in mythology. They are personified as overlords or past kings, as seen by one of the most important rivers in Northern Greece, the Strymon. Geographically, the river Strymon begins in Bulgaria and flows south into Greece, where it reaches the Aegean Sea. This river lies between the ancient cities of Amphipolis to the east and Argilos and Kerdylion to the west. While the river was not initially named the

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[2] Brewster 1997, 2.
[3] Grandjean 2000 85.
[4] Tsigarida 2011, 166.

Strymon, the name was attributed to it after a grieving Thracian king threw himself into the river after his daughter's death.[5] This act, along with his mythological birth from the Titans Okeanus and Tethys, allowed him to transcend to become a river god.[6] The Strymon embodied this violent end and demanded respect from anyone passing by. During his expeditions in Greece, Xerxes tried to cross the Strymon. In doing so, the first stopped and sacrificed to the god Strymon so that perhaps he could let them cross; although he lost a few men in the mud, he did end up passing.[7] The personification of water emphasized its importance and the need to connect with it. Water in mythology was either an obstacle to overcome, such as in the form of floods, or a way to strengthen oneself through nourishment or purification. Either way, these myths highlight the need and fear these water springs, streams, and great rivers incite for the Greek people.

There are various references to water as an obstruction in mythology. Two of said instances are from the labours of Herakles. The sixth labour of Herakles saw Herakles tasked with defeating the Stymphalian birds who lived in the Stymphalian swamp. This instance saw the swamp as a hindrance to Herakles, which he could not physically beat but had to find a way around. Thus, to outsmart the body of water, he used a *krotala* to bring the birds to him since he could not cross the swamp.[8] The tenth trial was to gather Geryon's cattle who were spread out around Thrace. Since the Strymon river separated Thrace, Herakles needed to be able to cross it. Similar to the other labour, the river became a hindrance to Herakles' mission. To combat this, he filled it with rocks so he could cross it at the cost of the river becoming unnavigable.[9] The danger that bodies of water can inflict can be seen in other instances within the mythology. For example, in book 21 of the *Iliad*, Achilleus encountered the rage of the river Xanthos because he filled it with blood and corpses. [10] While Achilleus ultimately won, the fight was a challenge; he would have almost drowned if the gods had not interfered. In all three mythological instances, water was an obstacle to surpass, a threat to the hero's quest, and a powerful force.

Nevertheless, this is only in some cases in the mythological record, while water can become an aid to the heroes in others. Concerning the fifth labour of Herakles, he had to muck

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[5] Ps. Plut. *Fluv*. XXI.
[6] Hes. *Theog.,* 339.
[7] Her. *VII*, 113-4.
[8] Krotala are bronze noisemaker clappers, similar to cassinettes. Walsh, Brown, et al. 2017, 446.
[9] Apollod. *Bibl*, 2.5.10.
[10] Hom. *Il.* XXI. 264-304.

out the stables of King Augeas. To complete the task, Herakles diverts the nearby Alpheios river to run through the stables so it could be cleaned within the day.[11] In this myth, the hero manipulates the water to aid him with his task. While this seems impossible, there is evidence on whether Mycenean Tiryns diverted a river to access new fertile ground for agriculture.[12] Thus, diverting the river was possible to aid either the hero or the city itself. Other instances that reference the positive aspects of water are within Homer's Iliad and Odyssey, where the emphasis is on the process of purification. The Iliad has two scenes which reference this. In the first instance, Chryses washes his hands in water before prayer and the sacrifice. Similarly, Agamemnon orders his army to bathe in a river to eliminate any residue from the plague that Apollo had punished them with.[13] This purification is not only seen in scenes of religious vigour or in cleansing themselves from bad decisions. In the Odyssey, Telemachus was welcomed into the home of Nestor with a bath to clean off all the grime accumulated from the road.[14] There is an understanding that water has a cleansing property in its fresh state and could be used to negate any impurities on the skin.

The Greek laws and regulations in circulation emphasized the importance of the population's access to water and the development of water management. Solon's laws are the first reference to water management in Greece that survives. While serving as Archon in 594 BCE, Plutarch reported that Solon encouraged using wells within 710m to dig wells. He also ensured that the citizen could use their neighbour's well if the water table was not reachable.[15] These legislations suggest that there was an effort to promote access to clean water. An inscription from Thasos emphasized that this was not an isolated phenomenon in Athens but prevalent in other parts of the Greek world as well.[16]

Outside private water structures such as wells and cisterns, there were regulations for fountain houses too. Fountain houses brought large amounts of water to the city, but the water was not endless. They needed enough water to provide for the neighbourhood. Thus, the officials instated quotas for how much water a person could take from these sources. As evident in the

[11] Mithen, Mithen. 2012, Chapter 4.
[12] Mithen, Mithen. 2012, Chapter 4.
[13] Hom. *Il*, I. 449. ; Hom. *Il*.,I. 312-4.
[14] Hom. *Od*. III.466-469.
[15] Plut. *Sol*, 23.5.
[16] Frag IGXII suppl. 353.5 from Thasos.

Life of Themistocles, Plutarch discusses that guilty perpetrators were fined for contravening theses rationing quotas.[17] To prevent this, some cities allocated guards and other officials to ensure water was appropriately distributed from fountain houses. For example, in Athens, there was a position called the officer of fountains, Κρουνών επιμελμτές. They were in charge of maintaining waterworks, establishing guard rotations at fountains, and ensuring the population followed the water regulations. The process of selection highlights the importance of this position. The selection was not a position allocated by lot but one through an election.[18] Thus, the person tasked with the job must have been a trusted community member. Themistocles, in the early fifth century CE, was the most famous holder of this position. It was a seat that held prestige, as seen by the records concerning Pytheus, where he was awarded a golden wreath in 333 BCE for restoring and maintaining several fountains and aqueducts.[19] While attested to only in Athens; it is not difficult for someone to occupy the same role in other cities, especially in the colonies of Athens, such as Amphipolis, or in cities that modelled themselves after Athens such as Pergamon where similarly they had the *astynomoi* who also took care of the water systems.[20]

As the mythology supported, the belief was that water was an agent that was able to purify. Although true, if the source was impure, it lost those abilities. While a future section will be dedicated to how the Greeks found a water source and which water source was most valued, it is essential to discuss the concern that the Greeks had regarding keeping a water source from becoming polluted. An Athenian inscription states that it was forbidden to soak hides upstream from the sanctuary of Heracles near the Ilissos river.[21] While it was unlikely that the river was used for drinking water, this legislation hints at a relationship between clean water and a better quality of life. Similarly, Pliny the younger commented on how the river running through the city of Amastris was a sewer more than anything else.[22] This suggests that there was a consciousness within the ancient world that water could be dangerous and human activity could pollute the water, making it unusable, ugly, and unhealthy.[23]

[17] Plut. *Them.* 31.1.
[18] Aristot. *Const. Ath*. 2, 43..
[19] Angelakis and Koutsoyiannis 2010, 1000.
[20] Klingborg. 2017, 91.
[21] IGP. 257.
[22] Plin. *Ep*. X. 98.
[23] Plin. *Ep*. X. 98.

The written source provides several attitudes toward water. For example, some sources warn that water is a hindrance, while others say it is necessary. The mythological tradition and legislation support these attitudes, suggesting that negotiating with both sides of water was essential for their lifestyle and survival. While evident in the literary tradition, this duality can be seen in how the ancient Greek constructed water features that survive today.

2.2 Environmental Conditions of Northern Greece

While approximately 2/3s of the world is water, only 1.5% of that is freshwater, and less than 3% of all water is not frozen by ice/glaciers such as lakes and rivers.[24] The problem with this 1.5 % is that it includes surface water that its environment or human activity can easily pollute. Thus, the ancient Greeks used to tap into groundwater since it had been filtered by the time it reached underground. The only issue is how uncommon it is at only .6% of all water.[25] Therefore it became essential to find fresh water and build cities near these sources to utilize it more easily. Before discussing the water structure the ancient Greeks used to manipulate it, some practical information must be disclosed.

The geological conditions of Northern Greece are an essential factor when considering how the ancient Greeks retrieved water since all water becomes groundwater and prime for tapping for civilizations. The second part concerns how these sources were found and how they chose which sources were good enough for their uses. Since not all water is equal, it is important to understand the Greek understanding of which water is pure and which is impure.

Greece has various geological conditions, each unique to each part of the country. The precipitation and temperature of the western Peloponnese will not be the same as the Ionian islands, nor will they be similar to Thrace. Greece's most notable common characteristic is its mountainous terrain and long coastline with typical Mediterranean temperatures of dry summers and rainy seasons from mid-autumn to mid-spring. Since this study concentrates solely on the finds in Northern Greece, the geological conditions of this region should be considered. The region of Northern Greece, more specifically Macedonia and Thrace, belongs to the third sub-

[24] Chapman-Davies 2008, 13.
[25] Chapman-Davies 2008, 13.

types of climates found in Greece whose climate is similar to the southern part of the Balkans.[26] Although Mediterranean in location, the fact that it has the northern winds coming in from the Balkans and Eastern Europe brings a cold front to the climate, making it one of the cooler regions in Greece. This can be seen in the fact that winters can get as cold as -20º C while still having scorching summers, equating the region's Annual Temperature Range (ATR) to be higher than 20º C, while most other areas have an ATR of 15º C.[27] These temperatures play an essential part in the precipitation levels and thus increase groundwater in the region. In the region of Northern Greece, the topography is very mountainous and has an abundance of trees that aid in regulating the water table in the region.[28]

The amount of water sources that can be tapped into depends on how much rain falls in the region and accumulates in the water table, becoming groundwater. Part of this rainfall flows over the ground collecting various kinds of surface water, such as still water or puddles, and flowing water such as rivers. The remainder of the rainfall filters down into aquifers, part of the bedrock that can absorb and transmit water into the earth, forming a natural underground reservoir.[29] The water is filtered throughout its descent into the ground, ensuring its good quality. Once inside the aquifer, the water flows on what is called the 'hydraulic gradient' or the slope of the aquifer. Throughout its movement, it is common for these waters to flow into a stratum of impermeable clay whose thickness allows the water pressure trapped inside to be greater than the atmospheric pressure called confined aquifers.[30] Following the gradient, the water escapes through holes in the bedrock and outlets, becoming a spring or flowing into another body of water, such as a river or sea, following the topography as it descends towards the lowest point.

While not all rainwater becomes groundwater, all groundwater is indeed rainwater; thus, it is important to confirm the precipitation levels in the region of study to comprehend the geological conditions in which the settlements live. Within Greece, the precipitation levels change throughout the region, with its yearly median being approximately 686.57mm, with higher precipitation levels in and around mountain ranges. At the same time, areas like the

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[26] As suggested by Mariolopoulos (1938, 1982). Seen in Zerefos, Repapis, *et als*. 2011, 28

[27] Annual temperature range is the difference between the highest temperatures of the year in July and August to the lowest in January and February. Zerefos, Repapis, *et als*. 2011, 32

[28] Antonarakis 2018,7.

[29] Chapman-Davies 2008, 14.

[30] Chapman-Davies 2008, 14.

Cycladic islands can receive as low as approximately 300mm due to the region's climate.[31] These regional differences differ due to the topography of each area, and since there are so many mountain ranges and a long seacoast, there is a variety. In Greece, the rainfall made by air mass depressions usually concentrates in the west and moves east and another that moves from north to south. Thus, in the mountainous and forested region of Northern Greece, a colder climate is common in the south; it receives less rain than the western part of Greece due to the protection of the mountains and the long coast that borders the south of the provinces.[32] The province of Central Macedonia, which centers around the city of Thessaloniki, has an average of 538.92mm of rainfall per year. In contrast, the province of Eastern Macedonia and Thrace has a higher level of 653.37mm per year.[33] Both regions are under the average rainfall for Greece, most likely due to their position on the northeast coast of Greece where the coast often affects the winds and its position on the east end, while the rainfall is usually focused on the western coast.[34] This changes inland, where the rain concentrates away from the coast. Thus, Northern Greece has a colder climate with a lower precipitation rate in comparison with the rest of Greece. While flooding is more frequent in warmer regions, Greece can experience such heavy rainfall that flash floods are a risk during thermal thunderstorms.[35] Due to the mountainous terrain, this water rushes to the bottom and collects at the coast during the dry season. These storms strike fast and hard, where visibility is low, and flooding can happen fast, especially with the mountainous terrain of Greece adding velocity to the rain as it collects in valleys, which act as conduits, and collect in the lower parts of the terrain. This phenomenon is more frequent in areas with less rainfall since there tend to be more days where rain falls heavily and creates flash floods. At the same time, in wetter areas, the people seem more accustomed to dealing with the rainfall, rather than in areas where it is less frequent and thus becomes less of a priority.[36] This is no different than what can be found in Northern Greece, where violent storms can hit hard in the summer. This violent rainfall and

[31] Angelakis and Koutsoyiannis. 2010, 1000. ; Zerefos, Repapis, *et als*. 2011, 33. The World Bank Group, 2021.
[32] Zerefos, Repapis, *et als*. 2011, 34.
[33] This average rainfall is the average from each year from 1991 until 2020. The World Bank Group 2021.
[34] Zerefos, Repapis, *et als*. 2011, 35.
[35] Zerefos, Repapis, *et als*. 2011, 34.
[36] Koutsoyiannis, Mamassis, Efstratiadis, Zarkadoulas, Markonis. 2012, 240.

flooding cases can be attested to in various forms throughout mythology and the archeology the ancient peoples left behind.[37]

Since topography, precipitation, and climate differed in each region of Greece, it would not be strange for each city to develop their ways of dealing with water, whether as a valuable source or a risk.

2.3 Quality of water

As previously discussed, since humans cannot consume salt water, only a small fraction of water can be used for human consumption. Out of this 1.5% of the world's freshwater, approximately .6% is allocated to groundwater, while .9% is surface water like rivers, lakes, and streams.[38] The scarcity of water developed questions concerning the acquisition of a good water source. How were freshwater sources found? How did they determine the quality of the water? Was there a hierarchy of water where each type was used for different purposes? These questions concerned the ancient peoples and were answered in their written legacy through the lens of ancient philosophers and historians.

One of the deciding factors in establishing a new city is its proximity to a freshwater source. This was the case for the Greek origins of Philippi, a settlement located in Thrace northwest of the modern city of Kavala in the Drama plains. This territory was originally Thracian before it was colonized by the Thacians in 360 BCE. The Thracians chose this spot specifically after the abundance of water sources in the area, highlighting their presence by naming the ancient city Krinides, meaning springs or fountains.[39] Providing a good water source for the city allowed for stability for the society where they could concentrate on other issues. This does not mean that all sources were adequate water sources. The writings of the philosophers Aristotle and Theophrastus have survived long enough to describe this thought process.

[37] The myths of Deucalion, Dardanus, Ogyges, and the various myths containing water from Heracles. Accounts by Plato, Hippolitus. And various architectural elements such as dams and land drainage systems. More on this from: Koutsoyiannis, Mamassis, Efstratiadis, Zarkadoulas, Markonis. 2012,
[38] Chapman-Davies 2008, 13.
[39] Hellenic Ministry of Culture and Sports. 2015, 155.

> Special care should be taken of the health of the inhabitants, which will depend chiefly on the healthiness of the locality and of the quarter to which they are exposed, and secondly, on the use of pure water; this latter point is by no means a secondary consideration. For the elements which we use most and oftenest for the support of the body contribute most to health, and among these are water and air. Wherefore, in all wise states, if there is a want of pure water, and the supply is not all equally good, the drinking water ought to be separated from that which is used for other purposes.[40]

In fear of getting sick, concern for a separate pure water source was needed for a healthy settlement. As previously stated, there were two freshwater sources that the ancient Greeks could tap into: surface water and groundwater. Once a good source of water was found, the most significant challenge the ancient peoples had when using surface water was overcoming the threat of contamination from nature, animals, and humankind since they were often used to dispose of waste. At the same time, groundwater is kept relatively safe since it is encased in bedrock and thus protected from impurities. There were various theories on how to test the purity of the water source. The first surviving account that refers to water purity and its connection to people's health comes from Alcmaeon of Croton, who lived in the fifth century BCE.[41] Hippocrates followed not long after suggesting that flowing waters "[A]re naturally the best. But they need to be boiled and purified from foulness if they are not to have a bad smell and give sore throat, coughs, and hoarseness to those who drink them."[42] Another way will be to study the pattern of animals and their well-being afterwards to determine if the water contains any impurities that might make one sick.[43] As a doctor, Hippocrates has the people's health in mind when he comes to a city to treat people as written in the sources that quote him.

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40 Aristot, *Pol.*, 7, XI.

41 Antoniou, Lyberatos, Kanetaki, Kaiafa, Voudouris, Angelakis. 2014, 107.

42 Flowing water means water with a steady movement in its course, such as rivers, lakes, or streams. Hippoc. *Aer.* 8. Further on this in Hippoc. *Aer.* 7.

43 Hippoc. *Aer.* 8.

> On arrival at a town with which he is unfamiliar, a physician should examine its position with respect to the winds and to the risings of the sun. For a northern, a southern, an eastern, and a western aspect has each its own individual property. He must consider with the greatest care both these things and how the natives are off for water, whether they use marshy, soft waters, or such as are hard and come from rocky heights, or brackish and harsh.[44]

Not only was there a concern for the purity of the water, but there was also an understanding of the scale of which waters were the best in accordance with the area they belonged to. The purity of the water was a concern for the population, and their goal was to tap into the purest source they could get. This allows us to understand that the ancient peoples were conscious of their water. By studying the water sources, they determined which were pure enough to drink and better suited for cooking or use in the workshop due to the impurities.

[44] Hippoc. *Aer.* 1.

3.0 Fresh Water Sources

Accessing fresh and pure water is more challenging than going to the closest source. As previously stated, the risk of contamination is a threat and is a concern when planning a settlement. There are two ways that the ancient Greeks obtained water. The first is through accessing nearby sources inside the city. These sources include artificial sources such as wells, cisterns, and natural sources from springs within the city. The second developed once wells and cisterns needed help to handle the growth of the settlement and its water demand. Thus, since the Greeks could not suddenly become nomadic, they brought a water source from outside their borders to them through the construction of aqueducts.

3.1 Nearby Sources

As the name suggests, a nearby water source is located within the city limits and thus easily accessible. While there are cases where this includes natural springs, such as the case of the Klepsydra in the Athenian Acropolis, the only human intervention that pertains to the project was the architecture built around the spring. Therefore, this section will focus on two manmade structures: wells and cisterns.

Both structures have a long history in various societies as successful methods of retrieving fresh water. They were ideal for smaller settlements due to being able to be built seemingly anywhere and were used in both the private and public spheres. That is until the settlements expanded, and thus, an external source had to compensate for the lack of nearby water. This phenomenon did not mean that they abandoned these hydraulic works. On the contrary, due to the overarching threat of war over the city-states, a law has been put into place that one must maintain these structures. While long-distance aqueducts were a great way to provide for their population, there was a fear that enemies would be able to find these water sources since they came from kilometres away and tamper with them to gain an advantage in their war.

> Suddenly falling upon Athens, it first attacked the population in Piraeus which was the occasion of their saying that the Peloponnesians had poisoned the reservoirs, there being as yet no wells there- and afterwards appeared in the upper city, when the

deaths became much more frequent.[45]

Thus, the upkeep of wells and rainwater cisterns would allow one to access a reliable water source during war. It also provided a closer source than the water access point of the springs or aqueducts, often in the form of fountain houses and set in public areas. For more wealthy households, wells and cisterns are found in the workplace or domestic sphere for private usage.

3.1.1 Wells

Wells are one of, if not the, oldest man-made structures in human history used to gain access to water. One of the oldest wells in Greece was attested to in Cyprus, dated before 8300 BCE.[46] Thus, when the Archaic period in Greece began, the technology for constructing wells was already developed and used for thousands of years.

Wells were vertical structures dug into the ground to access the water table and, thus, fresh groundwater. The water table is the level at which groundwater travels underneath the earth's surface and follows aquifers in a slope called the Hydraulic Gradient.[47] (Plan 1) This means that the land's topography dictates the water table height in each region and can be affected by various factors such as terrain, the location of bedrock, and the seasons. Sandy or rocky terrain will process water faster than earth or clay, allowing for the level of the water table to be more profound. The location of the bedrock is important because the bedrock is waterproof. Thus, it can collect water in its crevices and create aquifers easily, depending on where this bedrock is. If it is located under the earth, this creates an isolated area where water can flow at its own rate. If exposed, the water will run off its surface, collect elsewhere, or become stagnant for land creatures. In the wet seasons, precipitation filters through the land. It enters the aquifers to refill them and raise the water table.[48] In contrast, the hot summer months see less rainfall and more moisture evaporation in the air and ground, thus evaporating the groundwater and lowering the water table.[49] Another phenomenon that could empty part of the aquifer is when the aquifer hits the surface, breaking open the pressure inside and becoming an unconfined aquifer, allowing water to escape and become springs. When there is no break, the pressure builds, becoming more

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45 Thuc. VII.
46 Mithen, Mithen. 2012, Chapter 2.
47 Chapman-Davies 2008, 15.
48 Chapman-Davies 2008, 15.
49 Chapman-Davies 2008, 15.

than the atmospheric pressure and becomes confined aquifers until it hits a discharge point at the sea, coast, or a spring.[50]

Unlike today, where we have machines to dig our holes, manual labour was a key feature of digging wells. Although inexpensive to make, construction took time and hard labour to be able to dig deep enough to access the water table. Through the writings of Plutarch, Solon suggested that one should not dig more than ten fathoms, or approximately 18.3m, deep for a well if there is no water.[51] While 18.3m was the suggested max, wells could be as shallow as 3m and as deep as 30m since it depended on the location of the water table. The two wells at the Passage of Theoroi in Thasos are recorded to be 5m and 7m deep.[52] Water appears from the bottom when a well's depth hits the water table. As previously stated, the atmospheric pressure is lower than the pressure inside the aquifers, often allowing water to rise into the hole. This pressure also dictates the rate at which the water fills the well and at which level it stops.[53]

The interior of wells had varying widths, often set between approximately 0.5 to 2m in diameter. This diameter was just large enough for someone to fit inside to maintain the structure should it need repairs. The depth was always consistent with the height of the water table. The interior of the well had stone masonry, mortar, or sometimes even terracotta cylinder drums as lining. For instance, the well set near the Hellenistic theatre in Dion was lined with wedge-shaped bricks, while those near the Passage of Theoroi in Thasos had gneiss and marble. Large cylindrical terracotta pipes, like at Akanthos and in some wells at Dion, are interlinked to act as lining in rare cases.[54] (Fig. 1) This provided a smooth surface for the water to fill and protected the purity of the water from dirt, clay and rocks falling into the water from the interior. It also provided stability to the walls so that the water did not weaken the sides too much. Some wells were unlined, but these are few and far between, often because they were carved directly into the bedrock and thus did not need lining or were so close to the water table that it was unnecessary.

There are various names for the square or circular structure placed over a well or cistern's rim. Some call it a parapet or a wellhead, but for simplicity, this thesis will refer to this part of

[50] Chapman-Davies 2008, 15.
[51] Plut. *Sol*, 23.5.
[52] Grandjean 2000, 88.
[53] Chapman-Davies 2008,) 15.
[54] Trakosopoulou-Salakidou 1996, 303.

the structure as a puteal. The puteal were often made from stone or terracotta and gave the well an additional height to prevent foreign dirty water, objects, animals, or people from falling inside the well. These puteals contained water should the pressure inside the well try to cause the water to overflow. One example of this is found on the well in the courtyard of Akanthos, bringing the opening a few feet higher.[55] (Fig. 2) Sometimes on the rims of these puteals, grooves in the stone were made from the friction of pulling up water by the rope. Although it is unknown whether the water source under was a well or a cistern, these rope marks can be seen on the sides of the puteal from the Hellenistic house at Amphipolis. (Fig. 3) However, not all wells had grooves, as there is evidence that the Greeks built wooden structures with a central axis set above the wells to hang the rope and container and ease the action of lifting water from the well and prevent the wearing down of the stone. Lifting water also prevented the water collection container from hitting the sides of the well and possibly breaking. An example of one of these canopies was inside a well dug outside the Hellenistic Theatre at Dion. Here, marble capitals, column bases, and drums were found inside during the excavations.

Within the urban environment, archeologists uncover wells in all contexts, such as the sacred, commercial, and private domains. Well water was an easy way to provide a safe water source for sacred use when an area did not already have a source. As previously stated, it was a straightforward way to access a steady water source despite how much manual labour was needed.

Tradition often dictated that one must purify oneself when passing from different areas with different functions, such as from the everyday area to a sacred space.[56] The Passage of Theoroi has an example of this where the interior of the passage has two wells. This placement of the wells was not by chance. Not only were passages often marked with water to purify oneself, but there was also a link between the characters set on the reliefs on the gate and the wells. The relief on the west of the gate depicts Apollo and the nymphs, with another relief on the other side with three gods presenting offerings to the other gods. (Fig. 4) Since Nymphs were

[55] Trakosopoulou-Salakidou 1996, 303.
[56] Grandjean 2000, 85.

protectors of public waters such as wells and gushing springs or fountains, it is not strange to find images of nymphs close to water sources such as wells to commemorate this connection.[57]

Equally, well water was good for commercial activity. The best representation of wells used for commercial activities is on the southern part of the east side of the agora at the ancient city of Pella. (Fig. 5) Twelve shops are facing towards the agora, each with a uniformed well. These wells were within the front room, eight in the center front and four in the back of the main room, near the entrance to the back room. These wells are lined with stone and round with a circa 60-65cm diameter. The excavations of these wells provided scholars with information about what fell into the well, thus aiding in identifying the commercial activity in each room. In the case of these rooms, the many sherds found inside and around the well suggest the activity of selling and producing pottery.[58] This number of wells in this sector with this product type allows scholars to understand the importance of a nearby water source for pottery production or the identification of what was sold in the room, such as a well at Pella where various West slope vases were found. (Fig. 6) This allows us to recreate part of the city's economy through the wells' second life as a garbage pit.

Within the domestic sphere, two activities need a close source of water. The first is for the everyday lives of the Greeks for cooking, drinking, and bathing, and the second is for commercial activity, usually set inside dedicated rooms or the open courtyard. The households on either side of the main street that passes inside the Gate of Silene in Thasos have wells with evidence of both activities. The second half of the sixth century BCE is the date given to the first phases of these buildings. In both, gold and bronze workshops were set inside the courtyard of the households, suggested by the amount of residue left over from the metalworking activities. The courtyard acted as an open area that would vent any smoke from the metalworking and had access to the well nearby for the craft.[59] This well acted as a freshwater source for the family. At ancient Argilos, a well sits outside the Hellenistic mansion on top of the Acropolis. (Plan 2/Fig. 7) Excavations inside the mansion have provided evidence that olive oil production was the commercial focus downstairs of the household, while the family lived on the upper floor. At the same time, an above-ground basin sat in the corner of the courtyard. While this basin dedicated

[57] Grandjean 2000, 85.
[58] Llibaki-Akamati, Akamatis, *et als*. 2011, 68.
[59] Grandjean 2000, 123.

its water to the production of olive oil, the well outside allocates water for other purposes, such as the outside farm or the living quarters of the family that lived on the upper floor. As previously stated, wells tap directly into an aquifer; therefore, the well water produced is fresh and the best for consumption.

Wells were and are still used today because of the low cost to make and maintain. Although labor-intensive, they could be left to nature to provide water for the people with only the occasional repair made. The purity of the water can be easily maintained since the water was refreshed from underground, with the only risk coming from anything thrown in from above the well. However, wells can only sustain a certain number of people. Thus, finding other ways to provide water was necessary when populations began to rise in urban environments. These wells began to dry in certain seasons when too many people tapped into the water streams.

3.1.2 Cisterns

Cisterns are artificial tanks that act as storage for water. Cisterns can be above ground, although most are underground to preserve space, keep the water cool, and avoid evaporation during the dry season.[60] The context where these cisterns varied from settlement to settlement, but most often, they were placed under the courtyards or peristyles of domestic buildings to catch rainwater.

The placements of the cisterns were essential in the gathering of rainwater. Since the courtyards of houses were open air, it allowed for easy water transfer from the roofs to the cistern. The way the Greeks designed their roofs was essential to water harvesting. In the ancient world, ceramic tiles covered most roofs. These tiles were organized in a regular pattern, allowing the roof to not only seal the interior of the building from water damage but also direct the water off the roof in an intended direction. An example of this was Olynthus' House Bvi2, where the front two-thirds of the house leaned into the courtyard while the last was tilted towards the back for the rain to fall into the drainage alley between two rows of houses.[61]

[60] Yannopoulos 2017, 1026.
[61] Klingborg 2017, fig 13.

In the case of domestic houses, most roofs often lean towards the courtyard. At the roofs' edge, gutters would collect rainfall and funnel it directly into ceramic pipes, eventually bringing the water to the cistern to prevent further contamination or spill. Ceramic pipes delivered water from the eaves to the cistern. In house A6 at Olynthus, these linked ceramic pipes fit into each other with a width of 0.16m to protect the water quality from debris or impurities on the roofs. This ceramic pipeline was buried 0.30m under the courtyard and led to the settling basin, or prolakkion, before it entered the cistern.[62] This is not true for all cisterns. House Avii6 and Avii4 are two cisterns in the corner of the courtyard, eliminating the need to bury terracotta pipes to preserve the rainwater's purity from any impurities on the floor. Instead, the water collected would be eased into the cistern.[63]

Unlike the construction of wells, cisterns have various forms, such as flask, pear, or shaft.[64] Out of these, the flask cistern is the most popular in Northern Greece; more prominently in Olynthus.[65] (Plan 3) The first three forms are underground as it provided structural support for the cistern so that the water pressure from the amount of water did not damage the side walls. Cisterns can also be rectangular and circular, as in Stagira and Pella.[66] Cisterns can hold from 10 to 30m³ of water on average, depending on the dimensions.[67] Olynthus has an extensive repertoire of cisterns located in the houses, AV5, Bi5, and Biii2, among others, and has determined that the maximum volume these cisterns could hold was between 23 and 26m³.[68]

From the surface, underground cisterns look very similar to wells. The mouth of both cisterns and wells is often circular with a puteal or wellhead set on top. This gave the cistern more height of around 0.50m to bring it above the ground and prevent impurities or things from falling in. These puteals were often made from wood and thus not preserved. However, few have survived in stone or terracotta.[69] One example is at the Hellenistic house in Akanthos, where enough of the puteal has survived to show that it is of the same style as the wells.[70] (Fig. 2) To

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62 Cahill 2002, 243.
63 Yannopoulos 2017, 1026. ; Cahill 2002, fig 23.
64 Klingborg 2017, 20.
65 House A5, Av5, Bi5 and Biii2.
66 Yannopoulos 2017, 1026.
67 Klingborg 2017, 26.
68 Klingborg, Finné 2018, 117.
69 Klingborg 2017, 40.
70 Trakosopoulou-Salakidou 1996, 303.

further protect the water inside, a lid was often placed on top to protect water made of stone, terracotta, metal, or wood.[71] Puteal was sometimes overlooked, as seen at house Avii6 in Olynthus where instead, a rectangular cement platform acted as protection against foreign water.[72]

Underground cisterns had necks at the same diameter as the mouths of the cistern, where intake and outtake pipes distributed water. The neck often had small wedge-shaped niches thought to have been used to climb in and out of the cistern to repair and maintain the water tank. It is still being determined how these niches functioned: They could be niches to support wooden planks to descend as was used by miners, or perhaps scholars are overthinking it, and the niches are purely footholds.[73]

The intake pipes are close to the mouth of the cistern, where water enters the cistern. Sometimes, this pipe has a prolakkion or a settling basin set before it so that any sediment dragged through the pipes can settle one last time before entering the cistern. At Olynthus, 10% of all the cisterns had a prolakka.[74] The best-preserved prolakkion comes from house Av5. (Fig. 8) The rectangular structure was set at 0.95m deep into the ground and 1.55m long by 0.75m wide with terracotta pipes that brought water from the eaves towards the settling basin before transferring it to the cistern.[75]

As the name suggests, outtake pipes were designed to lead water out and away from the cistern. These pipes are not necessary for cisterns to function; some still have them. These pipes flow out of the cistern from underneath the intake pipe and expel any extra water in case the cistern overflows. Another way to combat the overflowing of cisterns is the introduction of a double-chambered cistern. While Athens was known for these cistern networks, there is evidence of one case at Olynthus in house Biii2. Inside the house's deep bell-shaped cistern is a terracotta pipe that connects this cistern to another 3m away. The second cistern, in comparison, was a shaft type with an opening of 1m in diameter and lined with cement with niches for cleaning and

[71] Klingborg 2017, 28.
[72] Robinson, Graham 1938, 122.
[73] Klingborg 2017, 45.
[74] Klingborg 2017, 38.
[75] Klingborg 2017, 40.

repairs.[76] This terracotta pipe is an overflow for the first cistern, allowing more storage space. This cistern also had an opening for access from the ground level. But since its placement seems to be in a separate room, the only way water enters is from the other since it gains its water from a terracotta conduit that catches rainwater from the eaves.[77]

Underground cisterns would collapse if they had no lining. Without a lining, cisterns would have become unstable fast as the water would brush away the dirt on the sides of the cistern while the bottom would soak up any stored water. Therefore, the lining of the cisterns was essential for storing water. Klingborg reports that more than 70% of all cisterns in his study of cisterns in the Greek world have some waterproof lining.[78] In Northern Greece, it is possible to observe two types of lining in underground cisterns. In the first case, the Greeks dug cisterns into the bedrock instead of the earth and clay, thus preventing the water from wearing out the sides. As an added protection, the Greeks often coated it with hydraulic mortar in case of cracks in the bedrock. An example is along the eastern Classical wall of the Acropolis of Stagira. (Fig.9) Here, a circular open-air cistern was dug 4m into the bedrock of the hill with a diameter of 1.80m. White lime mortar coats the walls of this cistern, providing a waterproof coat and keeping the water ground temperature.[79] This type of lining was also observed in all cisterns and some prokklia at Olynthus on both the Hellenistic northern and archaic sides of the city on the southern hills.[80] The lining found in the cistern in building BI5 was identified as lime mortar with a pinkish color due to the inclusion of crushed ceramic alongside the powdered limestone and approximately 0.03-.04m thick where visible. [81] For above-ground cisterns, there is no bedrock or earth to dig out the form; thus, the Greeks had to create the desired form out of stone. Since stones still have seams between each other, there is still a risk of leakage. Therefore, an interior lining was still a necessity. Stagira also had these above-ground rectangular tanks. (Fig. 10) The lining for this cistern was a rare case as thick lead sheets covered the stones instead of mortar to seal those cracks. Although this sealed the tank, it polluted the liquid. Thus, there is a chance that any water stored here had a different intended purpose.[82] The cistern supports this

[76] Robinson, Graham 1938, 309.
[77] Klingborg 2017, 243-4.
[78] Klingborg 2017, 43.
[79] Sismanidis 1992, 455.
[80] Yannopoulos 2017, 1026.
[81] Klingborg 2017, 44.
[82] Yannopoulos, 2017, 1026. ; Sismanidēs 2003, 50.

idea in the atrium of an excavated Hellenistic house at Akanthos. This cistern was a pithos set inside the ground and, like Stagira, was lined with lead sheets.[83] This courtyard has both a cistern and a well. In this case, well water was the preferred source since it was groundwater and thus had less contamination; thus, it was probably dedicated for domestic usage. Since the cistern would have contamination from both the roof and the lead lining, the water was used for the commercial activity of the household. The allocating of different waters could be true for Stagira, as one of such above-ground cisterns was in the same sector as the stoa and a commercial district and thus could have been used for the workshops.[84]

Underground cisterns often have an indent right at the bottom, in line with the shaft. Often circular and about 0.10-0.20m deep, these bottom depressions served as silt catchers.[85] Since the middle of this area was the lowest point of the cistern, any sediment that would have made itself into the water would have dropped or settled to the bottom and into this area. The bottom depression contained sediment and allowed for a focal point for cleaning in the dry months when the cisterns were empty. Birkner also develops a theory that this depression also allowed for an extra cushion when lowering a bucket or ceramic vessel, which could be heavy.[86] With all the water naturally flowing to the lowest point of the cistern, should the water level be low, they would not have to worry about the vessels breaking from hitting the bottom unless the cistern was dry. Of course, this depression can be exaggerated, such as in house Bi5 at Olynthus, where this depression was distinct, measuring 1.43m in diameter.[87] In other examples, the bottom depression is built into the cistern, such as in pear-shaped cisterns, since the cistern was not designed to have a flat bottom but instead rounded.

While built cisterns were a reliable feature of any household or area which needed a freshwater source, they were immovable and expensive to construct. An alternative option was the use of storage vessels. These vessels took the form of vases such as amphorae and pithoi. These vessels were placed above ground in the corner of the courtyards so that the gutters could deliver the water straight into the vessel, just like any cistern. House Aiv9 at Olynthus is one house where pithoi were set in two corners of the courtyard and in line with the gutters to collect

[83] Trakosopoulou-Salakidou 1996, 303.
[84] Yannopoulos, 2017, 1027.
[85] Klingborg 2017, 48.
[86] Klingborg 2017, 48.
[87] Klingborg 2017, 243.

rainwater.[88] Since these portable vessels could be moved out of the way and replaced should they need to store any other water. This suggests that the water could be harvested as much as they wanted if it rained enough to sustain it and could be stored in other areas of the household where they needed it the most such as the kitchen or bathroom. The vessels used as cisterns were common in the household, and since they were common, it would not be difficult to assume that these vessels were easy to get a hold of and, thus, relatively inexpensive. This was seen in other households at Olynthus, such as in House AV9 and AV1.[89] Thus, unlike underground and aboveground-built structures, storage vessels provided an inexpensive and portable way to gather water in a household if the roofs had gutters.

As previously discussed, there was a concern for the availability and purity of water in the ancient world; thus, the Greeks would routinely clean them. If this was not the case, more sludge or debris would be found at the bottom of these structures that would be able to date the life of the well, such as the case with some wells. Instead, this build-up of sludge and debris is from after the cistern's abandonment. For instance, at Olynthus, the latest sediment inside the bottom depression of the cisterns belonged to the time of the city's destruction in 348 BCE by Philip II, as confirmed by stray coins and pottery found in the sediment. [90] This also confirmed the difficulty in dating these structures. It is possible to obtain a rough idea of the cistern's abandonment. Still, the construction and life of the cistern can only be determined by using the surrounding environment and the dating of the structures in conjunction with the cistern. After the life of a cistern, these structures often have a second phase. The most common second phase is as a garbage pit, while others are known to become other structures such as storage or more rare constructions such as a prison, like at Philippi.[91]

3.2 External

The development of long-distance water systems has a long history outside Greece. Settlements developed and became cities not only on a structural level but because of the thriving population. These people lived in proximity to each other, and unless you were wealthy

[88] Cahill 2002, 109. Tölle-Kastenbein 1990, 107-8.
[89] Cahill 2002, 118; Cahill 2002, 122.
[90] Klingborg 2017, 55.
[91] Prison of Saint Paul was originally a roman cistern. Klingborg 2017, 54.

and had a private well or cistern, water had to be shared through public sources, some of which dried up during hotter seasons. The development of external sources came around when these public sources were insufficient to sustain the population using them. Since the population could not suddenly become nomadic to follow their water source, they had no choice but to develop a structure to bring water to them.

The first version of the long-distance water structure, the qanat, was first developed in the 3rd or 4th millennia BCE by the Persians in Asia Minor and the Levant. Qanats consist of one long underground tunnel large enough for human access with a smaller conduit under the floor tapped into a spring aquifer. Often 10-15km long, this underground waterwork is distinguished from the others by the sequence of vertical shafts every 20-30m that follow the qanat, providing light, ventilation and a quick access point for maintenance and cleaning. [92] After its development, the technology spread into various areas in the Middle East and North Africa where it is still being used today. While this exact structure did not make it to Greece, it influenced the development of the aqueduct. While its development is unclear, the Minoans on Crete were the first people who lived in Greece to use the aqueduct. Bronze age sites such as Knossos, Mallia, and Tilissos had open and closed terracotta pipes to bring water.[93] This technology would become apparent in mainland Greece sometime in the sixth century BCE following a population increase and the establishment of various cities as *poleis,* such as Athens, and Corinth.

3.2.1 Aqueducts

An aqueduct is an artificial watercourse that brings water from a freshwater source to a distribution point, often set inside a settlement. While the freshwater source could be any type, the ancient Greeks usually funnelled spring water into the structure since groundwater was superior to water that could be easily polluted. The aqueduct tapped directly into the spring from the aquifer's outlet to preserve the water source's purity. If there was a lack of spring, they could tap other sources such as streams, rivers, and lakes. From these points, the aqueduct often followed the land's topography and used the force of gravity to its advantage to keep the water moving toward its destination.

[92] Angelakis, Konstantinos Mariolakos 2016, 1317.
[93] De Feo, Angelakis, *et al.* 2013, 1999.

When one thinks of an aqueduct, one often thinks of the extravagant Roman aqueducts with their large size and impressive infrastructure. However, it is a lesser-known fact that Greece had aqueducts influenced by the Levant's Qanat and set underground. Burying was an inexpensive option, where the elevation of the aqueduct could be manipulated to keep a slope for the water to run and to protect the water source from the city's enemies. Ample curves and the bends in the topography also allow for the slowing of water should it be moving too fast. This reduces the pressure and prevents any cracking in the pipe.[94]

As previously said, the aqueduct developed in Greece around the sixth century BCE and allowed for various sophisticated watercourses such as the Peisistratus aqueduct at Athens, the aqueduct of Eupalinos at Samos, and the aqueduct of Flerio at Naxos. This development was also the case in Northern Greece. While Olynthus's aqueduct seems to have been developing since around the sixth century BCE, this seems to be the oldest in the region. Most other cities in Northern Greece seem to have developed in the fifth and fourth centuries BCE, such as Aigai and Thasos. The dating of aqueducts, like cisterns, is quite tricky since there is no pattern of stylistic choices at specific times rather than others with the expectation of an expansion of materials in the Hellenistic period. Instead, the data attributed to the water feature are associated with another object. For instance, the aqueduct at Olynthus was dated from the sixth century because sherds form a black-figure vessel found in conjunction with the waterline.[95]

As previously stated, the most popular way to tap into a water source was through access to a spring. While it is difficult to determine where each aqueduct tapped into a water source, the general area is relatively easy to determine. In the case of the fourth century aqueduct at Aigai, the trajectory of the pipes indicates that the water source came from the area in and around Agios Nikolaos, which were rich in springs, before entering the city through the fortification and delivered water first to the acropolis and the palace before descending the hill into the city.[96] There is one source that we can use to determine the location of the aqueduct's origins: the sanctuary near the ancient city of Aphytis. The spring was found in a cave, originally an area of worship for Dionysus and the nymphs just southwest of the sanctuary. This spring provided

[94] Sismanidēs 2003, 45-6.
[95] Although this could equally be the latest date that could be attributed to the Aqueduct since vases could be reused for years after its official date, thus the aqueduct could have very well been built sometime after this particular vase was finished. Cahill 2002, 33.
[96] Angelakis, Rose 2014, 178.

water for the fountain just outside the cave and the tanks in front of the temple of Zeus Ammon. (Fig. 11) Other than these two examples, the rest of the aqueducts found in Northern Greece have only a general idea of where the source was. Since springs from mountainsides are easier to transport toward the settlement since the momentum aids the water's velocity, the pipes' trajectory should point in the direction of the water source. This is the case for both Amphipolis and Olynthus. The fifth century BCE aqueduct at Amphipolis was found inside the city at the tanks in the *Gymnasium* and other places before exiting the city from the Northeast. The trajectory of the aqueduct would place the spring somewhere on the western side of Mount Pangieon. Olynthus has the sixth century aqueduct entering the city from the Northern gate at the head of Avenue A. (Plan 4) This trajectory allows scholars to determine that the most probable place for the spring water to have come from is the Polygyos mountains, 12 kilometres to the north-northwest of the city.[97]

Most Greek aqueducts are standard in appearance. Since they were underground, they needed a solid material that would provide protection from the impurities in the dirt and smooth inside so that it would not disrupt the water flow. In the Greek periods, this material was undeniably cylindrical ceramic pipes. The pipes were approximately a meter long and interlocked through female-to-male joints. These joints were not an absolute fit and could be prone to leakage. Therefore, there was often an adhesive made from lime, cement, or lead to prevent leakage and movement of the pipes while the water ran through them.[98] Mortar from lime still survives on the aqueduct pipes along Avenue A of Olynthus.[99]

Clay was used due to its malleable texture and waterproof quality when fired. Ceramic was also readily available, and potters could make it easier. It was also lighter than other materials, such as stone and lead and was more rigid than any perishable materials, such as wood or leather. Lead was another material used to make water pipes in the Hellenistic period. Amphipolis is such an example where lead pipes connected the aqueduct to reservoir tanks at the *Gymnasium*.[100]

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[97] Tölle-Kastenbein 1990, 75.
[98] Hodge, 2000, 41.
[99] Hodge, 2000, 41.
[100].Koukouli-Chrysanthaki 2011, 422.

These circular pipes had a diameter of around 0.20-25m, with water passing inside the pipeline, as seen in Stagira.[101] Water would only flow through half the pipeline to prevent a blockage in the pipes, observed through the regulation of calcium deposits left inside the pipes.[102] These clay pipes were often set inside a stone conduit only slightly larger than the pipes that were either built into the ground or carved from the bedrock in order the protect the ceramic. On top of these conduits were thick stones. These functioned as cover stones for easy access to the clay pipes for maintenance and cleaning. Thasos has an example of this at the gate of Zeus and Hera, where a gneiss slab, approximately 0.15 to 0.20m thick, covered the pipeline.[103] The clay pipes were also known to have holes set in the top of the pipes to be able to clean the calcium deposits inside. These holes were often circular or elliptic and, when not in use, were open and plugged up to stop spillage. The plug could be an assortment of materials. The aqueduct on the acropolis of Aigai had wooden caps, while the cleaning holes in the aqueduct of Olynthus had terracotta disks plugging them.[104] Additional holes were drilled into the tops of the pipes at Olynthus around these lids for future ventilation and flow of the water inside. [105]

The Hellenistic period saw a new, widespread technological development in water management. While a regular aqueduct allows water to be transported over long distances, it relies on the topography to generate gravity so that the water runs smoothly. The Hellenistic period saw the incorporation of the inverted siphon in aqueducts. Since aqueducts had to follow the topography and slope of the land, their path was long. The siphon eliminated this problem, allowing for the descent of the valley and climbing the other side without losing momentum.[106] The first variable is the transition of the aqueduct into pressurized pipes at the header tank before descending the valley's slope. This momentum of the water inside the pipeline escalates the pressure inside the pipes, creating a vacuum that propels the water up the other side of the valley to the receiving tank, allowing the water to continue to its destination.[107] Olynthus has the earliest pressurized water system dated to the Greek period in northern Greece, so far, dating before its widespread use in the Hellenistic period. These clay-pressurized pipelines lead to water

[101] Hodge 2000, 41.; Sismanidēs 2003, 45. ; Ouellet 2019, 172.
[102] Hodge 2000, 41.
[103] Grandjean, Wurch-Koželj, Kozelj 2011, 258.
[104] Faklaris1996, 72. ;. Robinson, Graham *1938.* 310.
[105] Tölle-Kastenbein 1990, 94.
[106] Angelakis, and Rose 2014, 177.
[107] Angelakis, and Rose 2014, 177.

in the city and towards two water fountains, one near the southeast edge of the Southern Hill, while the other set at the northeast edge of the agora on the Northern hill. The first pipeline is set around the sixth century, as dated by the black-figured sherd that was found alongside it.[108] This elicits the question of when and where the skill began to develop. The sixth century saw the development of large-scale aqueducts in large cities such as Athens and Samos; thus, was the technology of pressurized systems developed alongside that of regular aqueducts, or was it a regional accomplishment that did not spread? Alternatively, the dating of the pipeline was mistaken. As previously explained, dating aqueducts depended on ancient sources and artifacts found in conjunction with the pipeline. No matter the date, the second pipeline confirms that Olynthus had access to the technology of pressurized pipes since the pipeline led to the fountain at the agora on the north hill. (Plan 5) This fountain, along with the rest of the settlement, was destroyed by Phillip II in 348. Thus, it confirms that both of these pipelines were in working condition by the city's destruction and thus before the Hellenistic period officially began.

While the pressurized systems in Olynthus were made from clay pipes, siphons can be made from different materials, such as stone and a thicker clay pipe. The most popular material but most of them are made from lead and stone as they were less likely to break due to the pressure inside the pipe.[109] The advantage that lead had outweighed any disadvantages, including the health risk, as clearly stated by Vitruvius in the first century BCE.

> Water supply by earthenware pipes has these advantages. First, if any fault occurs in the work, anybody can repair it. Again, water is much more wholesome from earthenware pipes than from lead pipes. For it follows be made injurious by lead, because white lead is produced by it; and this is said to be harmful to the human body.[110]

While this compromise was initially made in the Hellenistic period, it is unknown whether the Greeks truly understood the health risks that lead brought to the population yet that consumed the water.

Once the aqueduct reaches the city, it would either be sent to a reservoir or brought to an access point such as a fountain. This is the case at the sanctuary of Zeus Ammon at Aphytis,

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[108] Cahill 2002, 33.
[109] Hodge 2000, 78.
[110] Vitr. *De arch.,* VIII, 6, 10.

where the water conduit leads directly to the fountain that sits outside the cave. (Fig. 12) The water would then funnel straight into the back wall of the fountain, where a bronze lion spout would deliver a stream of water onto a platform where women would put basins or pots for filling. Only one of these holes survived, but the probability of a second in the southern half is high due to finding a piece of a marble basin underneath the Roman cistern that collapsed into the earlier fountain.[111] This is also found at Olynthus, where there is a single strand of pipes in a conduit which, once inside the city, follows Avenue A, where it leads directly to the fountain house in the southern part of the settlement, bordering what might be the Agora of the city.[112] (Plan 3) In other cities, the water would be delivered to its intended customer. Instead, the pipes are split, bringing the water to various places. This split was sometimes through a distribution center, for example, at the reservoirs of Amphipolis, located in the *Gymnasium*, before it was delivered to the *Palaestra* and other areas. (Fig. 13) Other times, this split happens underground, and the pipes are sent in different directions. Pella is one city where this division was made, and water was sent to different locations for both private and public functions. One line provided water to the Pella bathhouse south of the entrance to the site, while another provided water straight into the reservoir of a private household.[113] Aqueducts were versatile and could be used in numerous occasions whenever water was called for.

The lifetimes of aqueducts, among other water systems, did not stop with each period of history, nor did they frequently change. These are often large-scale projects with hard manual labour. Thus, their lifetime lasted until they were no longer needed or destroyed. The water can still be repurposed, depending on what was needed. The water source at Aphytis has a long history of being used in the eighth century BCE as a sanctuary of the Nymphs before it was converted into a fountain with an aqueduct leading water to the tanks in front of the temple. Once the Romans took control of this water source, they used it to funnel water to the Roman baths before the sanctuary was abandoned. Years later, this source was converted to power a watermill to push the point further.[114] Other aqueducts were not touched. However, they were constantly monitored, with routine cleaning and repairs performed to prolong their life. One of the main aqueducts from Thasos is such a case. Built sometime in the fifth century BCE, the aqueduct that

[111] Tsigarida 2011, 169.
[112] Hodge 2000, 41.
[113] Llibaki-Akamati, Akamatis, *et als.* 2011, 56.
[114] Tsigarida 2011,169.

runs under Gate of Herakles and Dionysus stayed relatively the same before it was destroyed sometime in the Christian or Genosian period of the city.[115] Should they stop using the aqueduct, there are one of two reasons. Such as the case of Amphipolis, the fifth century aqueduct; the roman occupation saw the aqueduct replaced in the second century.[116] The second case seen by Olynthus is the destruction of the city and, thus, the destruction of the water system.

[115] Grandjean, Wurch-Koželj, Kozelj 2011, 223.
[116] Angelakis, and Rose 2012, 186.

4.0 The City

4.1 *Street Planning*

Within the city, hydraulic works depended on the settlement's topography and urban plan. The development of urban grid planning provided a regular plan for the systematic development of the city. Streets framed each building and provided horizontal and vertical walkways along the settlements. The buildings found between each street formed rectangular blocks with squared edges. In the city, often near the center, a large agora is the focal point of social, economic, and political society. The grid system appears first in Magnea Gracia in the eighth century BCE settlement of Megera Hyblaea, suggesting that the plan's conception was sometime before that.[117] Over time, the constant flux of destruction, reconstruction, and expansion of settlements allowed for ample opportunity to test new ideas on organizing their city to suit their needs. By the fifth century BCE, this system would be standardized and planned out before constructing a sector of the settlement or new city. The city of Olynthus was organized in both ways. (Plan 5) The southern hill was the older part of the city, with occupations spanning from the Neolithic period until the seventh century. This hill, although there is a grid plan, the building construction is not regular, nor do they follow the same plan. The Northern hill was later developed in 432 BCE and followed the grid plan with an organized street and building plan. Following the establishment of the grid system, the fifth century BCE would see its evolution into the so-called 'Hippidamian grid plan' after the famous Greek urban theorist Hippodamus of Miletus.

4.1.1 Hippodamian grid

Although wrongly credited for designing the urban grid plan by Aristotle, Hippodamus of Miletus contributed to its evolution.[118] He is the earliest known urban theorist, architect, and city planner. The surviving source that quotes Aristotle said he "wished to be a man of learning in natural science generally and was the first man not engaged in politics who attempted to speak on the subject of the best form of constitution." [119] Hippodamus approached the grid system from the theoretical rather than practical side of things, with his concerns lying with the city's physical layout and the question of how to order an ideal society. The accommodation of a community in

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[117] Cilliers, Retief 2006, 43.
[118] Burns 1976, 415.
[119] Arist. *Pol* 12 67b

the ideal city is how he formulated the plan. His theories would later aid in planning several cities such as Piraeus, Thurii, and Rhodes.

Another part of the Hippodamian grid plan was the division of the polis. Since his theory was theoretical, he divided the polis into a community of citizens before properly planning the physical equivalent. This division was a tripartite system based on three occupations: artisans, farmers and soldiers. Following this, the land was divided into three divisions of religious, public and private sectors to help these class systems.[120] This would eventually develop into the three sectors found in a city. While Hippodamus did add to the evolution of the urban system, Aristotle exaggerated his contributions because of his aid in planning the Piraeus and Athens. [121] Hippodamus's division and distribution of the city segregated it for a better organization to benefit each social class. Although he was named the apparent 'father' of Greek city planning, he only added to the urban grid framework that was already in function for hundreds of years, and the combination would be the basis for what future urban planners would base their research on for years to come.[122]

The urban development of the Greek polis was established all over the Greek world, including in Northern Greece, where various colonies were established. The first instance recording an instance of the Hippodamian grid plan in the north was linked with the building projects of Philip II and his successors.[123] They developed cities into this grid pattern to allow for more significant avenues and to allocate areas to different functions in the Hippodamian way. Two cities that follow this pattern are Pella and Olynthus. Both cities had this grid pattern. Olynthus is known for the grid plan of approximately five vertical streets and twenty more minor horizontal streets due to the regularity that came with the fast establishment and construction of the Northern Hill. While the agora and other sectors have yet to be wholly understood, the distribution and urban planning of the residential districts were precise. Approximately 64 residential blocks were calculated, with an average of 10 houses per block facing toward the nearest street with a simple drainage alley separating them.[124] Pella also had a regular residential area with horizontal and vertical streets, each rectangular block approximately 45m wide and 125

[120] Cahill 2002, 3.
[121] Burns 1976, 420.
[122] Cahill 2002, 5. ; Burns 1976, 423.
[123] Angelakis, and Rose 2014, 175.
[124] Cahill 2002, 27.

long.[125] (Plan 6) The center of the city also had an impressive agora with an administrative and economic presence covering ten city blocks.[126] The agora provided a center to allocate to these activities, separated them from the residential sector, and kept specific sectors with similar activities together. For instance, In the south portico, the ample number of bones and amphorae suggest that this sector had shops dedicated to butchery and selling imported wine from Kos, Knidos, and Rhodes, among others.[127] Similarly, The northern portico has no evidence of commercial activity but instead has focused on administration, supported evidently by the changes in the standard architecture of the portico and on the number of papyri and tablets, some with the seal of the office of the polemarch of Pella stamped onto it.[128] The standardization of a city with clear areas dedicated to specific activities not only aided foreigners in finding their way around the city but also allowed for the standardization of water management.

The grid pattern provided an organized urban landscape where streets were placed regularly and were generally the same width throughout the length of the street. Streets allowed for more effortless traffic flow and ample space for hydraulic features. Roads were the best place to put water supply pipelines and drainage channels. Since roads were for everyday traffic, the channels were dug into the road with flat rocks placed above them to prevent contamination or anyone falling in. Inside the channels, the elevation would be tampered with to provide a nice even slope so that the freshwater or drainage water would direct itself to where it was needed. Roads were open spaces dedicated to easing traffic in the city. With the only built structures being walkways, it was easy to install in ancient settlements where these channels had to be incorporated into the existing urban plan. Constructing conduits underneath already established buildings was unnecessary and more trouble than it was worth. Digging up a street to put in a water system was more manageable, especially in cities with a grid plan. In these cases, the grid plan already provided regular streets that eased the construction of drainage and water supply systems. Thus, city planners only had to direct the water supply into the street where the reservoir was or to the fountain houses or other buildings that needed a water source.

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[125] Llibaki-Akamati, Akamatis, *et als*. 2011, 56.
[126] Llibaki-Akamati, Akamatis, *et als*. 2011, 67.
[127] Llibaki-Akamati, Akamatis, *et als*. 2011, 68.
[128] Llibaki-Akamati, Akamatis, *et als*. 2011, 69.

On the other hand, drainage used this technology in reverse, where the streets collected wastewater before directing it outside the fortifications via the streets. Similar to how Pella's and Olynthus' grid systems are straightforward, the reliance on their hydraulic systems was as well. For instance, at Pella, their monumental street plan was established in the fifth century BCE and was maintained until the city's abandonment. The water source was channeled through conduits set on the sides of the paved streets and directed the water supply to a distribution center before directing it to various other buildings like public fountains and the Greek baths.[129]

4.1.1.1 Baths

Since fountains were briefly discussed in the aqueduct subsection, the only public building with a strong connection to water that needs to be discussed is the public baths. Unlike fountains, which were generally straightforward, not all baths looked alike. Baths were found in various places, with different functions attached to them. Each function then gives the baths a different structure and water system. The two main functions found in baths are education and sanitation.

In terms of education, the *palaestra* was a center for educating young men in physical abilities, among other things. After exercising in the wrestling rings or the *Xyrus*, the men are full of sweat and dirt. Therefore, having a bath in the compound is essential for their education and sanitation. This is the case for the *palaestrae* in the palace of Pella and in the *gymnasium* of Amphipolis. These exercise facilities gather water from a nearby system of water reserves. At the Palace of Pella, this set of fourth century BCE reservoirs is south of the hypostyle bathing complex and north of the *palaestra*, feeding both with water. [130] The bathing in these features differed depending on what was needed. The baths in the northeast of *palaestra* (building V) in the palatial complex at Pella held a single pool with dimensions of 7.5 by 5m with a depth of 0.95m.[131] (Fig. 14) This pool was considered the cool baths where men would enter and exit the bath via the staircase on the northwest side. This pool was filled with water funnelled in by an open-air cistern to the east of it. A circular hole in the west was used as a drain when the pool

[129] Makaronas 1966, 101. ; Llibaki-Akamati, Akamatis, *et als* 2011, 56.
[130] Llibaki-Akamati, Akamatis, *et als* 2011, 62.
[131] Agiamarniotis 2016, 27.

water was emptied.[132] While these large pools allowed people to soak in, other *palaestrae* had a different system for bathing. Amphipolis had two sets of bathrooms along the *palaestra's* northern wall, with its northeast bathroom better preserved. (Fig. 15) Along both sides of the northern wall, water feeds into the walls through lead pipes and follows them until they reach the rooms needing water.[133] (Fig. 16) The water escaped the walls through circular holes with spouts that would guide the water into marble troughs set upon marble stilts. The northwest room was repurposed after the earthquake when the Romans rebuilt the *gymnasium* leaving holes in the wall, a few clay pipes and the remanence of the marble stilts and troughs.[134] In contrast, the northeastern room had troughs placed on all four sides, with the entrance to the room in the middle of the southern wall. The water could also flow through each trough via the holes on their sides, sharing the water between them. (Fig. 17) The young men would bathe themselves with the water from these troughs by standing before them. Any water splashing on the ground from their bathing or the overflowing of the troughs would flow through the floor and follow a series of drainage channels out the eastern staircase. (Fig. 18-19) These were baths set aside for bathing after physical activity designed for young men's use during their education.

While Greek households often had private baths that would have been used to take baths, there were facilities dedicated to public usage. The facilities, called *βαλανεια*, were often large and elaborate, with various rooms for different baths and activities related to the baths. The developments of baths in the Greek period are perfectly summarized by examining northern Greece's oldest and best-preserved Greek bath. The bathing facility at Pella is located just south of the main entrance to the archeological site and covers approximately 563.5 m^2 of land. The building is estimated to have been built during the last quarter of the fourth century, and its final destruction was dated to the large earthquake that destroyed most of Pella in the second century BCE.[135] This bathhouse had three phases which outline the development of bathhouses from simple one-pool areas to a multiroom and multitemperature complex.

The first phase establishes not only the limits of the bathhouse but also its clean water source. (Plan 7) This phase was dated by the presence of coinage from Philip II and Alexander

[132] Agiamarniotis 2016, 27.
[133] Agiamarniotis 2016, 30.
[134] Agiamarniotis 2016, 30.
[135] Akamatis, Aamodt, Gisler 2015, 24.

the Great and various west slope vases.[136] This early bathhouse consisted of one cold water pool set in the center west of the facility with a cistern to its south, an open courtyard, and various rooms such as *ἀποδυτήριον* (changing rooms) and rooms for business. The pool was 7.5m long by 4m wide and 0.60m deep. (Fig. 20) It was filled with cold water taken from the two water sources in the area. The first was a cistern which collected rainwater from the open courtyard. The other was from the city's aqueduct. It fed straight to the pool by clay pipes from the eastern side of the bath, where it followed the streets. This pool also had an overflow pipe which regulated the amount of water that the pool held.[137]

The second phase of the bathhouse, also dated by various coins from Cassander and Demetrius, was reconstructed around the second quarter of the third century BCE.[138] (Plan 8) This stage provided much change to the interior and exterior of the building. Two new rooms were constructed in the center north and center, with clay tubs lining the walls. With these rooms came the introduction of heated water in its most basic form. Due to the lack of any surviving heating elements in this period, it is thought that the water was boiled elsewhere outside or inside the baths before being transferred into the respective rooms via clay or copper vessels. This is supported by the various black soil layers found in both areas.[139] The first new bathing room constructed was a circular room with a diameter of 4.9m and was thought to be the hot room.[140] (Fig. 21) Clay tubs were lined around the room's walls with a central pebbled floor to waterproof it. This room was also enclosed, so the heat could not escape easily. The second room was square, approximately 4m by 4m, with 18 tubs lining all sides.[141] (Fig. 22) This room was considered a warm bath due to its proximity and similarity in design to the hot room. This room also had a clay pipe, .15 to .20m wide, which led from its south wall between two tubs, and evacuated water out of the baths towards the south of the facility to be vacated into the city's drainage system.[142] In terms of the exterior of the building, the open courtyard is also closed up at this point to keep the hot air inside the baths.

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[136] Agiamarniotis 2016, 13.
[137] Agiamarniotis 2016, 13.
[138] Agiamarniotis 2016, 14.
[139] Agiamarniotis 2016, 17.
[140] Lilimbaki-Akamati, Akamatis 2007, 100.
[141] While there are no exact measurements of the room, the central pebbled flooring was measured to 3 by 3m with bathtubs of .9m lining all the walls. Thus the measurement is a rough estimate based off the measurements taken from the following source. Lilimbaki-Akamati, Akamatis. 2007, 103.
[142] Lilimbaki-Akamati, Akamatis. 2007, 103.

The last phase is dated to the last quarter of the second century BCE. (Plan 9) This period saw the introduction of a permanent underground heating system that predated the hypocaust system of the Romans. (Fig. 23) A kiln was constructed underground and was placed between the circular and square rooms with a staircase to access it. From the kiln, air ducts distributed hot air to various rooms from east to west.[143] The introduction of this underground kiln disrupted the facility when it was constructed. Thus, the Greeks repurposed the circular room and built another room to be the hot bath. The circular room thus became the steam room. The tubs and the water system were removed to make room for seats along the edge, and places for vases full of hot water were placed to create steam. [144] The functions of the cold pool and the tepid square room did not change. Instead, they built another oblong room to the east of the new steam room. This room had a small pool, 1m wide, where the hot water would be deposited, and the hot air ducts would keep the room hot to make a more pleasurable experience.[145]

The purpose of these baths, like at Pella were clearly for the population's wellbeing. While the cycling of water could have been more most sanitary, the idea of there being a place where people could come and clean themselves when they wished must have aided in the overall sanitation of the city. While most wealthy households had a bathroom where they could wash themselves. The chances that the lower class had a bathtub were low. Thus, this provides access for a good portion of the population. The factor that they, too, made upgrades to the water system and created a heating system and more baths suggests two things. The first is that the baths were being used, and they needed to create more room. The other thing is that the heat was something that they enjoyed in the baths. Thus, baths were not only good for the physical health of the guests but also their mental health.

[143] Agiamarniotis 2016, 16.
[144] Lilimbaki-Akamati, Akamatis 2007, 103.
[145] Lilimbaki-Akamati, Akamatis 2007, 105.

4.2 Urban Drainage

While the constructions made to hold and transport fresh water sources are aids to settlements, this water is eventually used and disposed of. Funnelling wastewater in the closest street is the quickest disposal method. However, this hindered the settlement since the used water was impure and was known to harbour sickness and other pollutants. This is equally true with rainwater and flood water from thermal storms. Therefore, drainage systems were developed to combat this wastewater accumulation to prevent any health hazards collected in the polluted waters.

Drainage systems are not a new concept in the ancient Greek world. The presence of drains is found in settlements as old as Habuba Kebira in Mesopotamia, dating to 3500-3000 BCE.[146] In Greece, structural drainage is observed in the Minoan palace of Knossos. Underneath the palace are stone conduits that caught waste and stormwaters before channelling them through pipelines. This stone drain was made of limestone and was covered in a waterproof coating, preventing the conduit from leaking, and creating a smooth surface for the wastewater to run through the east end of the settlement and release its content into the Kairatos River.[147] Following that, each region adapted itself to dealing with waste and stormwater in its time frame. For example, Miletus had its own drainage system by the eighth century BCE with Delos a little after. Other cities such as Pergamum, Rhodes, and Athens began in the Classical period and were standard in settlements afterward.

Like the water distribution system, urban drainage channels relied on the grid system to use the streets to direct wastewater away from public and private areas and out of the settlement. Topography is also essential to the technology of water channels. While the water distribution system used gravity to bring fresh water to the settlement, drainage used topography to direct wastewater away from the settlement. The degree of human intervention needed depends on the settlement's layout.

When the slope of the hill is deep, the natural pull of gravity brings waste and flood water down the hill. When there are no after-features, the rocks which form the streets become

[146] Tamburrino 2010, 39.
[147] Mithen, Mithen 2012, Chapter 4.

slippery. Some roads built their streets in an attempt to make these hills less slippery. One way in which they did this was by placing rocks in a vertical fashion instead of flat. This provides a rough surface to grip with their feet as they descend. (Fig. 24) On the hill's slope, often smaller drains peak out of buildings to deposit all impure water from within into the street, such as seen on buildings at Argilos and the lack of city drains found at Stagira. At Argilos, two clear areas showcase how the streets were used as dumping grounds. On the main avenue in the Koutloudis sector, there is a stone conduit that peaks out of the unexcavated northeastern side of the site. (Fig. 25) This stone conduit is large and set inside the terrace wall of the avenue. The conduit is elevated, thus, any waste that would have flown through it would have spilled onto the edges of the avenue. The second point is on the plateau sector of the archeological site. This sector seems to be made up of wealthy houses set on a perpendicular set of streets. There is a spout which comes out from under the threshold of a partially excavated house on the western side of the north-south street. (Fig. 26) Like the conduit on the large avenue in the Koutloudis sector, this one is also slightly elevated off the street. This once again allows for any waste from the house to drop onto the rocks. What is also interesting in this area is right after this spout, it is possible to see the change in the street formation that was mentioned previously, almost as if this spout as well as any rainwater that would travel down, made this particular part of the road slippery. (Fig. 24)

Built urban drainage was often placed in points of high-water volume. These points were usually flat terrain, terrain set under a large slope, or terrain with a high volume of water-related buildings. Settlements with flat terrain need drainage to prevent waste collection all over the city. Olynthus is this type of settlement. Between each block of houses, a drainage alley collects waste from the houses surrounding it and the rainwater that collects from the back half of the roof of the houses that are not reserved for collecting water for the cistern. These drainage channels are lined with stone and mortar to make them waterproof and lie in the middle of the alley so that any foot traffic that needs to get into the homes from the alley does not step into the channel. (Fig. 27) Since the terrain is flat, the alley slopes to compensate for the lack of gravitational pull and pull the water outside the settlement. The smaller stature of these drainage systems is due to the small about of waste that needs to be collected. Although at Olynthus, they act as the primary drainage system directing all the waste and flood water out through the fortifications, these smaller drainage channels could link up to a larger-scale drainage conduit to keep the waste together and direct it all in one direction.

In terrain set under a large slope, a large drainage channel is necessary to deal with the waste and flood waters properly. These large slopes are usually the sides of a mountain or hill where floodwaters come rushing down during thermal storms or heavy rainfall. Drainage channels are placed strategically to collect these problematic waters so that water does not linger. For example, the Gate of Silenus from Thasos has a drainage channel running along the main street leading to the gate. This gate is southwest of the acropolis, set at the bottom of the hill. During heavy rainfall, the water that falls on the acropolis rushes down the sides of the hill. Inside the city, the hot spots for possible flooding include the southwest and western sides of the acropolis, and the lowest point is this area called the gate of Silenus. This point was also known to be flooded due to a rise in the water table. Thus, the combination of both factors saw frequent flooding in the area and still floods today.[148] (Fig. 28) This channel was built in the fourth phase of the gate somewhere between 340 and 330 BCE. It is square and measures 1m by 1m.[149] It was installed on top of the previous street when the street level rose to prevent flooding.

In areas with buildings that used a lot of water, or outdoor activities, drains were common. One such area was the *gymnasium* at Amphipolis. (Plan 10) At the *gymnasium*, a large sewer led from the acropolis and runs 66m diagonally from the northeast to the southwest across the area. (Fig. 29) This sewer was 1.6m in height and 1.7m wide and made from large upright blocks of porous stone with large flat slabs of the same material used as cover stones to prevent anything or anyone from falling in and to keep the functionality of the area. This large sewer collected water from numerous areas in the *gymnasium*. One such area was the *palaestra*. The northwestern corner had a reservoir that used clay pipes to funnel water into the *palaestra* walls directly south of it. Water would leak out from various holes carved into the walls and into troughs for the athletes' use. Excess water would splash onto the floors, where stone conduit would pick it up from the entrance of the rooms and deliver it outside the eastern side of the building. Although the specifics concerning the original outlet for wastewater were unknown in the primary phase of the *palaestra*, the outlet from the second phase of the structure, around the first century BCE, is assured. After a raid, the *palaestra* was rebuilt, with the main entrance

[148] Grandjean 2000, 124.
[149] Grandjean 2000, 125.

moved from the eastern side to the northern side. The northern staircase became the expulsion point for the wastewater, suggested not only by the end of the drainage channel but also by the wear on the stone steps from the continuous pass of water. Although this phase belonged to the Roman period, the Greeks likely used a similar technique. (Fig. 18-19) Therefore, this pipe could have been the original drainage route used in the primary phase of the building. Either way, both routes lead towards the large sewer in front of the eastern side of the building to carry the waste away. This large sewer also picked up the drainage from other areas in the *palaestra*. The stone altar just north of the *palaestra* had a pipe that fed directly into the sewer. (Plan 11) This altar was designated for sacrificing animals, suggested by the presence of four stone bases with metal attachments used to tie animals before being sacrificed at the altar.[150] One pipe led from the north of the *gymnasium*, past the reservoir, to the northeast corner of the altar, before another pipeline left the altar before funnelling any waste into the sewer due east. Why this drain connected the altar to the sewer has yet to be determined. It was possibly a freshwater source brought to the altar to wash the animals before their sacrifice, with the excess water flushed into the sewer. Alternatively, it could be a drain to take away blood from sacrificing animals. Another area at the *gymnasium* where drainage prevented the accumulation of impure waters was at the Paradromis, the open-air running track, and the *Xystos*, or the closed running area. This area had a drain installed vertically, approximately 40m inside the *Xystos*'s western edge. (Plan 12) This drain was a branch of the large collector previously mentioned and connected with the sewer near the *palaestra*. Lazaridis K. suggested that the collection of rainfall was one purpose of this drain. He believed that further north of the *gymnasium* was the location of a possible theatre, a theory that has yet to be excavated, and that this collector cleared any rainfall from the theatre.[151] This collector also aids in draining the center of the Paradromis from any water lingering in the area, just like the larger collector would collect any waste or floodwaters from the acropolis to the north of the *gymnasium* and allow for continuous use of these areas.

The size of the drainage system that takes care of each area depends on the settlement's terrain and the buildings and functions in the area. Smaller systems are in areas with less drainage, such as from building to street drainage, while smaller alleys will have small conduits. When the amount of waste and flood water increases, so does the size of these conduits, as seen

[150] Karagiorgis 2019, 8.
[151] Lazaridou, 1989, 550.

at the Gate of Silene in Thasos and Amphipolis' *gymnasium*. The Greeks manipulated the topography in these situations, so less human intervention was needed. The manipulation of the slope allows the wastewater to flow by itself and remove any risk from within the city. Within the context of drainage in public, two districts need further consideration since the drainage pattern is particular: the Agora and the Theatre.

4.2.1 Agora

Alongside the development of the grid plan, the agora began to emerge. The divisions of the settlement into public and private allowed for centers such as the agora to emerge and flourish. The agora was a Greek settlement's social, administrative, and economic center and was a common feature in most cities. This center was often in one of two places. Near the center of the city, as seen at Pella, for easier access from any point in the city and reflects its central part in the ancient people's lives, or near to the harbour of the city, as seen at Thasos, for easy transportation of goods from the sea to the shops. Either way, the agora consisted of open areas and built structures attributed to different functions, with foot and vehicle traffic walkways. Administrative, economic, political, and religious functions were all activities in the buildings surrounding the agora and the open spaces; thus, it was a highly visited area.

Regarding drainage, the essential factors are the presence of workshops and the area's popularity. As suggested in the second chapter, workshops usually have nearby water for production use. This freshwater becomes impure after use and disposed of. It is still questioned whether the shopworkers threw the waste right out onto the streets and thus into the path of other people walking on the street in front of the shop or into any nearby unoccupied spots around the agora. The agora's popularity features high traffic, the presence of animals, and the waste that comes with both. Thus, the drainage of the agora provides an easy way to clean up any other wastewater they have accumulated. A high volume of people and animals also made reducing the potential for floods or the accumulation of stagnant wastewater a priority to not halt the traffic due to street flooding.

Some agorae had a specialized drainage system built into the center of the court to counter any wastewater disposed of by the workshops, people and animals, and rainwater. In northern Greece, the agorae of Pella and Thasos both feature this drainage system. (Figs. 30-31)

Each of them has a square or rectangular agora, with the drainage system set on the perimeter of the open court in the center. The drain consists of a stone conduit made from various slabs of stone set in a line to form one continuous channel. Periodically, settling basins were set along the channel to collect any sediment. If sediment had collected in the conduits, it would cause the conduit to block and the wastewater overflow into the agora, creating the exact problem they were attempting to prevent. Settling basins collected these particles until the people assigned to clean the conduits could tend to them. The corners of each agora also had settling basins. They acted to collect particles and slow down the water so that the water could follow the curve and change direction toward another part of the agorae.

This drainage feature has yet to be securely dated. In the three settlements, Philippi, Pella and Thasos, where this feature is present, all three have Hellenistic and Roman occupations, and thus is the estimated development date in the agora or forum. Although the feature is usually found in Roman settlements, it could also belong to the Hellenistic period of these sites. Beginning at Philippi, a similar drainage feature is apparent on the outskirts of the forum. (Plan 13; Fig. 32) The difference in this feature is the nonexistent settling basins and the cover stones placed directly on the conduits. This suggests that the wastewater that flowed in these conduits was only water as no sediment could have entered between the cracks of the cover stones, supposed once again by the lack of basins. The plan of this forum has been thoroughly explored, and the earliest date of construction of this area was the first century CE and already included this drainage feature.[152] Since the original Hellenistic agora was not located underneath the Roman, verifying the period it began is impossible. The addition of the drainage feature was fundamental in the plan of the forum, suggesting that it was already a tradition for large open spaces.[153]

While Pella and Thasos also have a Roman occupation, the drainage in their agora is the standard example. At Pella, the agora was used from the fourth century BCE until the first century CE. Therefore, if there was already a standardization of drainage at Phillipi in the first century CE, this example of drainage at the agora must predate this. During Pella's Roman occupation, the urban plan remained the same as the original plan established in the Hellenistic

[152] Sève, Weber, 2012, 12.
[153] Sève, Weber 2012, 12.

period. [154] The same pattern is seen at Thasos as well. Therefore, as it survives, the agora was dated to the fourth century BCE or later. Grandjean suggests that the underground sewage systems that evacuated water out the northern and northeastern sides of the agora were installed sometime around the third century BCE. [155] Since the two water systems were linked, this sewage system and the conduits and settling basins surrounding the edges of the agora would have had to be constructed simultaneously.

Thus, the presence of settling basins is in itself an indication of Greek influence. The evidence suggests this point when one compares a forum and agora. While both are public spaces, the forum was for administrative and political reasons, with no economic sphere on the perimeter. This is seen at Phillipi, where the closest shops were on the south side of the forum and opened up to the larger sewer collector on the other side to be closer to the market.[156] This starkly differs from the Greek agorae found at Pella and Thasos. On top of the administrative and political aspects, the presence of workshops and shops demands settling basins to remove their waste.

4.2.2 Theatre

Theatres were often set on the sides of hills near the city's outskirts or essential sanctuaries. The hills created a natural slope for the structure to be built on so that the Greeks did not have to construct a support for the upper levels of the seats but instead could place wooden or stone seats to get the desired effect. In Northern Greece, there are three Greek theatres where drainage is recorded: Aigai, Dion, and Phillipi.

While theatres were not at risk for wastewater, drainage was necessary to evacuate rainwater. The hillside that the theatre was set on creates a slope that would catch any rainfall. This water would flow naturally and toward the lowest part of the topography. This lowest point would be the orchestra. Since the chorus, the area was generally flat and would have collected rainwater. Without any drainage, this water would become stagnant and provide an obstacle for the actors and spectators who had to walk up the orchestra to reach the staircase, allowing them to reach their seats.

[154] Llibaki-Akamati, Akamatis, *et als.* 2011, 56.
[155] Grandjean 2000, 62-3.
[156] Sève, Weber 2012, 12.

The base form of each drainage channel is standard. Each theatre has a single channel carved from the bedrock or constructed through the linking of stone, which curves around the exterior of the orchestra right in front of the *prohedria* or the first seats of the theatre. This allows all the rainfall to collect in the drains and not on the orchestra. The channels themselves had a range of shapes. The theatre at Aigai was built sometime in the second half of the fourth century BCE and had a small semi-circular conduit drain. (Fig. 33) In contrast, the Hellenistic theatre at Phillipi and Dion had large square conduits.[157] These conduits were generally left uncovered apart from the passage leading towards each row of seats. The ends of each conduit were either open or closed. The closed end ensured that any rainwater collected in the conduit flowed in one direction. This is the case for the Hellenistic theatre at Dion. (Fig. 34) Here the northwest corner was closed with the Southeast open. The open conduits continue outside the orchestra through the northern *paradaos* to dispose of the water. Other conduits found at theatres had both sides open, so the water was sent in two directions. The theatre of Aigai is such an example, where the eastern end of the orchestra sees the conduit continue in an unknown direction, while the western continues off towards the sanctuary of Eukleia and other parts of the city. [158] (Plan 14) The drainage conduit found at the Hellenistic theatre of Philippi is standard, except for the ends of the conduit. Instead of leading the water to each side of the orchestra, they continued towards each other before the water collected all together under the orchestra and was evacuated through a single conduit out the south towards the nearby portico and further into the city's water system. The Romans would eventually add to the channel, but the form would ultimately remain unchanged.[159]

The drainage system inside a theatre relies on the topography in which it was set. The hill it sat on provided a larger surface and slope for the rain to run down. This created the issue of flooding in the orchestra. Inserting a drainage channel at a lower elevation attracted the rainwater and provided an outlet for the water. With that, the first purpose of the drainage channel was complete. The leftover water from this would then run throughout the city drainage system, flushing out any waste still in the systems.

[157] Kaiafa, Papanikolaou, *et als* 2014, 178, 183, 188.
[158] Kaiafa, Papanikolaou, *et als* 2014, 178.
[159] Kaiafa, Papanikolaou, *et als* 2014, 189.

4.3 Domestic Drainage

The development of a regular grid plan provided an organized plan for public districts and works and the standardization of housing. Cahill had a point when he wrote, "A city is built for its citizens to inhabit, and in some ways the most crucial and yet least understood part the process determining how the community will interact with its physical environment, and how the physical environment should be tailored to fit the community." [160] Streets framed city blocks and allocated a specific area for constructing households or other buildings. These buildings generally conformed towards these organized blocks, as seen at Olynthus or Pella. While this is needed to have a clear and organized settlement, it is also to the benefit of the households and stores. The blocks allocated to the construction of households and stores are also standardized and could be built fast since they are similar, while the inside could be customized for the needs of the individuals who dwell inside. With the connection between urban planning and public works already established through the means of streets, households and shops can also take advantage of this proximity.

Although shops are commercial buildings, they have been included in this chapter on domestic drainage due to their interconnectivity to the household. Although some shops were found outside the home, commercial activity was often performed inside the inner courtyard or peristyles in the cases of wealthy households. In contrast, more modern homes used the front of their home to fabricate their goods. Thus, it is difficult to separate the two domains due to their dependency on each other.

4.3.1 Households

When discussing the household, the topic of the wealth of the family living inside is unavoidable. The more money an *oikos* has, the structure gains in size, the materials become more permanent and better quality, and a variety of rooms with different functions develop inside. Regarding low-cost housing, homes were small and often made from perishable materials such as mudbricks. These structures were one or more rooms with functions often overlapping in each room for sleeping, cooking, storing, and working. Because of the materials, these houses are hard to identify due to those construction materials not surviving. In contrast, middle and

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[160] Cahill 2002, 22.

high-class housing was more luxurious. These *oikoi* were larger and made from more sustainable materials. The larger floor plan allowed archeologists to identify different functions with different rooms. One distinction that is apparent in the division of the rooms is the public and private spheres. A central courtyard or workshops room with perhaps an andron was dedicated to commercial activities and hosting guests. Other rooms, such as kitchens, bathrooms, and male and female quarters, were private and dedicated to the use of the family. If these luxurious homes had a second floor, often the woman's quarters were set on the second floor for privacy. These homes also often had stores and workshops incorporated into the layout. While this could be found in the courtyard, it could be in a separate room with access to the street or outside the home completely.

The introduction of water features in the home depends on the division of wealth. Water must have waterproof material to gather, hold, and direct it. In low-income homes, the permeable materials cannot sustain this, or not permanently. Thus, if there was any evidence of drainage, it has not survived. With more sustainable materials, such as the stone found in middle and high-class households, they are more suitable as it takes more water to erode them. Middle-class households may have a single drain for convenience, while wealthy houses may have more. The Northern hill of Olynthus is known for its high-income households where, although not fully explored, approximately 1 in 3 private houses had a drain that carried wastewater outside the home through terracotta pipes and a storm drain.[161] This depends on the division of functions per room. A single room used for cooking, commercial work, and bathrooms only needed one outlet for the wastewater. In high-income houses, there is more room space, with each room assigned a different function. Thus, cooking, commercial work, bathrooms, and other water usage functions were in separate rooms and thus sometimes had their private drain. This is only furthered if they had a private water source such as a well or cistern. The wealthier a household is, there is more chance that drainage would be found since they had the resources and the cash to add this convenience.

Most of the drains were permanent features constructed into the side of the buildings. However, this does not mean that all of them were permanent. In Q9 at the ancient city of

[161] Angelakis, and Rose 2014, 184.

Argilos, excavations have shown the presence of a single stone conduit leaning up against the Southern wall of the building, right beside the threshold. (Fig. 35) The position of the conduit is key. It is leaning, U side onto the side of the wall, with the end on the occupation floor. It would have been impossible for the conduit to be used in the position it was found in. The position also indicated that certain care was put into the placement of the conduit, as it could not have fallen into the position, suggesting that someone had placed it there. Therefore, the most possible answer would be that the conduit would have been temporary drainage if used inside the house. Placed probably on the threshold to evacuate any unwanted waters.

4.3.1.1 Courtyard

Present mostly in wealthy homes, the first room where drainage was usually found was inside the courtyard. Courtyards were open-air spaces set near the center of the household and had no roof in order to let light and air into the home. The lack of a roof also provided an opening for any weather phenomenon. Water from the surrounding roofs would be collected in homes with gutters and a cistern, but any rain falling directly on the courtyard would be too impure for harvesting. The collection of rain or other fluids in this area created a need for stone paving. If not, the ground would create a muddy and difficult space to use by the homeowners or any visitor the owners might receive. This stone paving would sometimes be reinforced to ensure a consistent flow in the wastewater. At Argilos, it is possible to see in the paving of one courtyard that lead was used as a sealant to prevent any liquid from entering the cracks. (Fig. 36) The courtyard was optimal for a workshop or other commercial activity due to the ventilation, light, and plenty of room to work. The Villa of Bronze at Olynthus has an example of commercial activity in the courtyard. The main evidence comes from the large 1.9m wide doorway that opens into the courtyard with grooves set into the stone from repeated entry and an exit of carts or other wheeled vehicles.[162] The presence of these carts indicates that the area was used for moving large objects and for there to be wheel marks; this was a frequent reoccurring action. The presence of a workshop could also mean the frequent use of water, should the action need it. The wastewater from this activity would have had to have a place to go. Although the courtyard was paved, this did not actively remove the water from the premises. Instead, the Greeks installed drains. Certain households at Olynthus seem to accept the drainage channels in

[162] Cahill 2002, 98.

the center of city blocks as an extension of their property. The courtyard itself is paved and leaves the back wall of the house open, so there is no obstacle for any wastewater. Some of these houses include House AV9, AVII5 and AVII7. This is suggested by how clean they were kept in these areas. Other houses left rubbish in the alley since they did not have to see it daily. In houses like AV9, if one went into the courtyard, there was no wall to block out the sight; therefore, it was kept tidy.[163]

Two styles of drainage were used to dispel any water from the courtyard. Both styles used the same principle. In manipulating the slope of the courtyard, the Greeks could direct any wastewater towards a certain point. This first style pertains to the courtyards placed near an exterior wall of the house. At the bottom of this wall, it is possible to see a deliberate hole. The slope of the courtyard leans towards this wall, allowing for surface-level drainage. House AVIII9 at Olynthus showcases this, while House AVIII4 has a similar principle but has a small conduit as a guide. (Figs. 37-8) This type of conduit is not unique to Olynthus either. At Pella, both of the courtyards at the House of Dionysus use conduits to remove water. (Plan 16) The northern yard has a single conduit that crosses the peristyle to the west and exits the building. (Fig. 39) The southern courtyard was larger and, because of that, had two conduits used to evacuate water. The upper conduit evacuated the waters into the northern wall, passing under the flooring until it reached the drainage alley in one of the eastern rooms. The southern conduit led to the southeast, underneath the exterior wall and into the street. These small drains set in the wall not only provide an outlet for rain but also for any sediment that was left over in the courtyard.

The second way the Greeks rid their courtyards of water was by gathering the liquid by using ceramic pipes before directing it out of the courtyard. At Olynthus, this type of drainage was used in house Aiv9. This pipeline was approximately 7.1m long and sloped 0.44m to dispel the collected wastewater into street V.[164] (Fig. 40) As seen in the figure, the courtyard is in the center of the building and thus has no direct outlet into the street or drainage outlet. Thus, the pipe was used as an extension to keep the entryway clean. This is not always the case. House

[163] Cahill 2002, 118.
[164] Robinson, Graham 1938, Plate 92.

AV6 has a courtyard near the exterior south wall and still has a ceramic pipe directing wastewater.[165]

4.3.1.2 Kitchen Complex

The kitchen complex is a series of rooms dedicated to the family's well-being. It is found mainly in wealthy homes since this complex was often divided into three rooms: the kitchen, the flue, and the bathroom. Out of these three rooms, the bathroom is where drainage was usually found. The small and rectangular rooms were often placed off the kitchen and against the exterior back wall. Like the courtyard, this room is also paved. At Thasos, the northern corner has apartment buildings where both the bathroom and the kitchen area were stone covers the floor to waterproof it.[166] Stone was not the only material that could have been used to waterproof these areas. At Olynthus, various houses, such as house A2, have terracotta tiles paving the floor. (Fig. 41) Similar paving, but in stone, was found at House A in the Kamberidis sector at Argilos.[167] Hydraulic mortar has also been a method of waterproofing the area.[168] Waterproofing of this room indicated the presence of water, future supported by the frequent finding of bathtubs or fragments of bathtubs inside the room, hence the name 'Bathroom'. Some wealthy households lack a bathroom, and a bathtub can be found in the kitchen, such as in House A8, where fragments of the bathtub were found. [169]

The bathtub has a long history in Greece, dating to the Mycenean and Minoan palaces.[170] However the archaic and classical periods were when the presence of bathtubs was more widely spread. While the form changed over time, the form was standardized to be heavy rectangular structures built out of fired clay during the Greek period. Due to their heavy form, bathtubs were often dug inside the ground in order to ease movement inside and out of the tub. The back half of the bathtub is flat to act like a seat, while the other side sinks to create space for the feet of the user. Since it was still a tub, the walls around the seat and leg area rose to keep the water inside when someone sat in. The tub's sides rose around the bathtub seat for maximum comfort when bathing, while the walls near the feet were kept low for ease of entering and exiting. Sometimes,

[165] Robinson, Graham 1938, Plate 96.
[166] Grandjean 2000, 101.
[167] Malamidou, 2021, 316.
[168] Cook 1959, 38.
[169] Cahill 2002, 137. ; Cook 1959, 38.
[170] Cook 1959, 35

it is possible to find a drain at the bottom of the bathtub to empty it quickly. In some cases, when the tub is in use, lead, among other materials, was used to plug the hole, as was found in situ in House Q1 at Argilos. (Fig. 42) In this case, the bathtubs were drained by removing the stopper and releasing the water into another vessel before removing it. For the cases in which the tubs did not have drains, the bathtubs were emptied by hand or by tipping the contents onto the ground should they have a handle.[171] The bathroom flooring also may suggest which method was used to remove the water. Since in wealthy households, the tub is surrounded by paving, it is more likely to have no drain and be let out onto the floor, as seen at Olynthus. (Fig. 41) In cases like at Argilos, where the ground is stamped earth, it is more likely that there are drains so that, like with the courtyard, it does not become a slippery and more arduous work environment.

Considering only the confirmed houses in building Q, Argilos also has drainage channels. The houses at Argilos are noticeably smaller than those at Olynthus and Thasos but still wealthy enough to have more than one room. The tripartite house of Q5 has clay *louterion* broken into pieces in the southeastern corner of the front room. While this *louterion* is located on stamped earth flooring, there is a deliberate hole in the wall dedicated to the drainage of this basin. (Fig. 43) This hole was created in a purposeful way seen in the placement of the stones. Both sides of the hole have stones placed vertically, while the rest of the wall was built by placing the rocks horizontally. Between the two rocks that stand vertically sit flat rocks .38m wide, which would have acted as paving for any way to flow through and not create a muddy environment. While the rest of this room has yet to be excavated, there is a building S2 with the same type of drainage hole that was excavated. (Fig. 44) Here, while the drain's entryway is smaller at 0.26m the paving continues for over 1.04m inside the room. This drainage area is paved to stop the area from getting muddy with vertical stones at its limits so that the dirt flooring of the building would not get muddy. Thus, since the drainage holes are similar, what will be found in S2 will most likely be found again in Q5. In the smaller house of Q1, we already established that there was a bathtub with a drain at the bottom, but what was not established was the stone drain that was incorporated into the western wall right beside the bathtub. (Fig. 45) The proximity of the drain to the bathtub leaves no ambiguity. They were used in conjunction with each other. The western wall has flat stones covering the space between the bathtub and the wall, creating a

[171] Cook 1959, 35.

paved path toward a small opening in the wall. Inside this opening is a flat stone set into the wall and extends out on both sides, with rocks set horizontally on top of the drain. The part that extends out of the house comes to a point and is carved to create a tapered spout. At the same time, the exterior resembles what was found at a house in the Northern Quarter at Thasos. (Fig. 46) There is no clear path in which other stone would direct the wastewater, indicated by the smooth surface of the wall with no clear breaks that would indicate something was there. Instead, it would seem as if the wastewater was left to gravity to fall to the street. The tub's design points to the comforts of washing one's body, with various sub-uses concerning the kitchen since it is in such proximity. Either way, the bathtub was a luxury item found not only in the bathrooms or kitchens of wealthy households that could afford to buy them but also began to appear in middle-income households during the classical period despite there being other ways to bathe themselves.[172] The bathtub itself was also precious enough to warrant repairs should it break. The universal way the Greeks seemed to fix broken bathtubs was similar to any other ceramic vessel, using lead. Lead is a soft and flexible metal that melts easily. This provides an optimal material to melt onto and seal cracks without harming the ceramic. Repairing the bathtub proved that replacing the structure would be more complex than repairs.

Another drainage feature in this room allowed wastewater to exit outside the establishment. The common element of each house with a bathroom is that it is placed right next to an exterior wall for fast and efficient evacuation of water waste. While the hole intended for the waste to drain is not always obvious, they are separate exits of large bodies of water. For instance, at Olynthus, house Aiv9 has a bathroom set along the southern exterior wall with a drainage alley on the other side.[173] Although there is no indication of drainage on the room's surface, it could be located underneath the ground since there is no single construction of the drain. For instance, also at Olynthus, there are slits found at the bottom of the floor level of house Avi5, which let out any water on the ground into the nearby drainage alley. Nevertheless, another structure called house ESH 4 cemented the floor level and has two channels for drainage. (Fig. 47) One ceramic pipeline is located inside the southern wall and funnels the wastewater out of the room into Street I. On the northern side of the room, an open conduit led towards the north of the building. The location of where the conduit leads is unknown, however, it seemingly

[172] These other ways include going to public baths, washing at fountain houses and bathing from a basin.
[173] Robinson, Graham 1938, Plate 92.

follows the exterior wall past the bathroom and into the flue.[174] Some other households have drains made of stone found underneath the bathroom or kitchen, as seen at Thasos. One of the buildings in the city's Northern Quarter, labelled apartment three by Grandjean, has a stone-paved bathroom and kitchen, which shares a wall with a north-south street.[175] The higher elevation of the occupation floor created a slope for a small drainage conduit to keep its continuous gravitational flow out of the building. (Fig. 46) The conduit, made of various sets of stones, turns towards the north to hug the building and keeps the slope with a stone covering set on top of the conduit so that any waste may be deposited into the street.

The examples shown above have exclusively confirmed the presence of drainage from bathrooms into the street in households. This is the case for lower-class households, as seen at Argilos.

4.3.1.3 Andron

The andron was a room located in wealthy households for entertaining guests. This room was strictly for the presence of men to hold banquets and conduct business. The luxuriousness of the decorations inside further emphasizes this. Fancy banqueting couches called *kline* surrounded the room's walls, leaving only the door open for foot traffic. Under the *kline* were concrete platforms set to elevate the guests. The walls were often decorated with frescos, and the floor often had a single elaborate mosaic. This room broadcasted the family's wealth, going as far as using fancy decorated ceramic vessels for the banquet to impress the guests. Since there is an emphasis on the wealth of the room, it would not be odd for a certain cleanliness to be kept in the room so that the wealth may continue to show. [176] The frequent appearance of a drainage channel further supports this.

Since Olynthus is a city with a concrete city plan, it is possible to determine that drainage channels were found in half of the androns found.[177] This channel can be either open air as seen in the andron of House Avi 4, Avi 5 (room A), Avii 4, Axi 9, BV 7 and Bxi 1, or closed channels, as seen in House A10, Avi 5 (room D), and BI 5. The open channels are open spaces in

[174] Cahill 2002, 158, Fig. 33.
[175] Grandjean 2000, 101.
[176] Vitr. *De arch.*, VII, 5.5
[177] Robinson, Graham 1938, 175.

the elevated concrete platform for the *kline* and open toward an open hole in the wall where the waste would be released. In the case of closed channels, the platform covers the channel and the hole in the wall to save space and hide the drain from their guests. This drain is also why most of the androns were placed with one of their walls alongside an exterior wall. Most drains led right out into the street or drainage alley, although others used basins to catch the wastewater. Both methods were used at house Avi 5. (Plan 17) Room A is a larger room at 8.70m long and 4.95 wide. The open channel is located on the east side of the room and into the wall before evacuating water into a basin set in room B right next door to be emptied by hand. The Andron in room D is much smaller. The drainage channel is a closed type which runs underneath the raised platform and through the wall. The channel ends directly into a drainage alley built in conjunction with the house Avi7 set to the east of Avi 5. Although the reason why they would employ different techniques is not concrete, it is known that wastewater will flow to the lowest point, thus, since both androns sent off their waste to the east, it is possible that there was a natural slope to the east. Accordingly, they did not have to put extra effort into creating an artificial slope. This is further suggested when examining the frequency of androns with drains appearing in houses with even numbers. For instance, block AVI has only one house that has an andron with a drain on the northern, while on the southern part of the block, there are three (Avi4, Avi 6, Avi 8) of which have androns set along the exterior wall next to the entrance and use channels to flush water out onto street VI. This can easily be explained by a gradual slope that would naturally direct the waste out of the room.

Androns needed drainage for two reasons. The first concerns the nature of the room. Banquets were known for their excessive consumption of wine and food. During these parties, the room itself was bound to get dirty with wine and food stains. Hence, water could equally be used to collect all the waste in the room before letting the slope push it out via the drainage channel. The second reason behind keeping the room clean concerns the wealth in the room. With each room use, the couches, frescos, and mosaic floors are bound to get dirty, if not by the food and drink left, but by the dirt tracked into the room by the guests. Thus, if the room itself was a way to promote one's wealth, the precious decorations must be in full eye view and kept clean to draw the guest's attention. Thus, cleaning, especially the mosaic set on the floor in front, was a way to further one's reputation. Thus, the channel would have probably been used to carry away any dirty water from cleaning the decorations.

The family's wealth dictates more than how many rooms, paintings, mosaics, or household items. Wealth can also ease the lifestyle of those who live there. Wealthier people are more likely to have a private water source and drainage for that used water. One does not need a drain in their andron, but a good portion do to ease cleaning. They are also more likely to have multiple drainage systems found for the same purpose but in different areas of the home for an easier lifestyle.

5.0 Fortifications

Fortification walls were constructed primarily to keep enemies out of the city and protect the city's occupants from foreign invasions. In doing so, this also blocks the exit of anything or anyone inside the city, including any wastewater used by the citizens and any flood water from thermal storms. Therefore, water outlets were constructed into the walls to evacuate any waste while being small enough that enemies could not enter.

There are two types of manmade outlets found in Northern Greek fortifications. The first was created in conjunction with the gates of the city. City gates were already controlled passages where foot and vehicle traffic could pass and were set in line with streets. This allowed for the direct passage of wastewater without making allowances in the stone wall. In streets with no drainage passages in and around the streets, the street acted as a canal for any wastewater and was immediately directed outside through the gate. In other cases, structures are built to help direct this water. At the ancient city of Kerdylion, only the fortifications have been excavated. (Fig. 48) The east gate was uncovered in the 1997 excavation, where two drains ran above the street level. One of the drains ran on the side of the gate and to the side of the basin, while the other ran along the length of it. Both channels combine in the southeastern corner of the basin before following the rock channel through the gate where the water is ejected from the city.[178] In other cities, like at the gate of Silenus at Thasos, this channel is set underneath the gate, following the large collector that was set underneath the road. (Fig. 49) This collector was installed simultaneously with the sewer on the above street. As previously stated in the section on city drainage, this area had a troublesome relationship with water. Since it was the lowest part of the region, water from the surrounding area, along with the hill of the acropolis, ran down the hill to this spot. While it was only built in 340-30 BCE, there were many other attempts to combat the water, such as raising the street twice before they created this system. This collector was functioning even in 250 BCE when the neighborhood was ultimately abandoned. Today, we can still see flood water's effects on the neighborhood and how water passes under the gate. (Fig. 28) Another outlet was underneath the earth at Thasos and was seen under the floor of two rooms beside the maritime gate.[179] The sewer was built in the first half of the fourth century BCE and

[178] Ouellet 2019, 141.
[179] Ouellet 2019, 68.

was approximately 1.42m high and 0.72-.46m wide, depending on whether the measurements were taken from the top or the bottom of the channel. Inside this channel, a pipe was inserted to ease the flow of water and waste from the agora.[180] In other cases, the main street is the conduit allowing direct access to the gate and for all rainwater and waste to wash away, as is the case for Argilos. This is also the probable case for some of the waste and flood waters at Olynthus. In the center of the northern hill, the housing blocks with drainage alleys set between them. These alleys direct water toward the exterior of the blocks. Thus, they do not connect to the next block next to them or the next drainage alley. Thus, there is no continuous stream of drainage that leads to evacuation holes in the fortification but instead is let out into the street so that the southern slope of the hill would direct the water along the street and out the southern gate of the city.

In cities where evacuation outlets are placed underground in large conduits, there is always a risk of this passage being used by unwanted people. This is a risk that the Greeks took and even tried to prevent. Bars were inserted in various ways to block the path at important intervals. (Fig. 50) This is evident in Thasos. The gate of Hermes has two drainage conduits that evacuate wastewater from the street as well as rainwater from the Acropolis. Both of these have iron bars that block the conduit from unwanted entry or exits for the city.[181] The knowledge that the sewers were actually used at entry points to the city is suggested not only by the iron bars blocking entryways but also by how some of these entryways have more than one set of these bars as if there was a successful attempt. They had to seal the conduit at another stop to secure the exit again. This is the case at the Gate of Silence. Underneath the gate, the conduit was blocked by nine iron bars, all of which have disappeared, although the holes in which they were inserted are still there. Two are placed vertically in the southern most part to the conduit before the canal, which leads the water outside the fortifications. Further north, towards the city's interior, were the seven leftover iron bars placed in the same vertical directions, presumably to block any entryway to the city further.[182] Thus it is suggested that neither set of bars was enough to do their intended purpose; thus, more were implemented. These bars are found in channels that lead out of fortifications and conduits into the sea. Under the maritime gate, the large

[180] Grandjean, Wurch-Koželj, Kozelj. 2011, 293.
[181] Grandjean, Wurch-Koželj, Kozelj. 2011, 415.
[182] Grandjean, Wurch-Koželj, Kozelj. 2011, 186.

conduit also has three iron bars 0.66m long inserted to stop any entryway from the port while allowing any wastewater from the Agora to escape the city. [183]

As already discussed, the fortifications' second way to evacuate wastewater from the city was through specific exits in the wall. The exits are vertical or horizontal holes set at the height of the ground for any rainwater or waste build-up to exit the city at low elevations. Often these holes are constructed simply with two vertical slabs of rock with one horizontal on top to create a seat for the rest of the wall above it. The difference between the horizontal and vertical exists solely in the dimensions of the hole. The western fortification wall of the northern hill at Olynthus has horizontal water exits. (Fig. 51) These holes were placed at intervals throughout the wall. What is interesting about these exits is that the houses A (1-13) were placed with their western wall acting as the fortification wall. This allowed for much more room in the house and a personal outlet for their wastewater. These outlets were also in line with a rectangular roo,m which would have acted as a drainage alley that came off the courtyard, thus, it would naturally bring out the water from the home. Vertical wall slits are more common to find in settlements. Stagira has numerous ones in their classical fortification wall built around 480 BCE. (Fig. 52) Since most of these water evacuates were placed on top of the acropolis, it suggests that this was an area where water would collect and thus needed to be drained. The holes were shaped in a trapezoidal pattern, with a larger opening inside the acropolis, and the vertical flat rocks would tap in toward the exterior of the wall. This created a funnel for the water to accumulate in and be directed out from. This tapering does not only direct water but also prevent unwanted people or larger animals from entering illegally. [184] In Northern Greece, Amphipolis has a unique system of water conduits set inside its fortification wall. The Northern wall has various points where similar trapezoidal conduits are strategically placed.[185] Most of these conduits come in groups of three, while areas with heavier rainfall during the torrent season have more, as seen between the Thracian gate and a tower where a total of 15 conduits were placed in a single line. (Fig. 53) While only the foundation of this set of conduits remains, another section of the fortifications has seven conduits approximately 0.22m wide with six piers separating them in better condition. (Fig. 54) Like at Stagira, these conduits act as a funnel to gather any water and evacuate it from

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[183] Grandjean, Wurch-Koželj, Kozelj 2011, 293.
[184] Ouellet 2019, 172.
[185] Ouellet 2019, 200.

the city's interior. In comparison, the Amphipolis systems are massive at approximately 1.5-1.9m in height, indicating the amount of water that had to pass through the fortifications. [186] The amount of flood and wastewater that passed in this area is further suggested by transforming the nearby Classical gate into a separate water system and creating a higher Hellenistic gate right next to it. [187] (Fig. 55) Although these water conduits were mostly for the torrent rains, there was evidence of evacuation holes reserved for water from specific places within the city. West of gate Beta were two sets of three conduits with a stone channel leading straight to the eastern before continuing along the wall's interior and ending at the second set of conduits. (Fig. 56) There are two possible reasons for this. The first could be that these conduits formed a sort of sewer system and wanted to contain whatever water was being directed inside the conduit. This is suggested because Amphipolis already had an extensive sewer system, as seen in high risk of flooding areas such as the *Gymnasium*. This conduit could have also been a means of controlling the water output in that single area. The set of 15 conduits was just west of these smaller ones, thus suggesting that such a large quantity of water must have passed through this area. Either way, these conduits directed unwanted water away from the city to prevent waste or rainwater from becoming a hindrance.

Once through the city walls, there are three patterns to how the Greeks dispose of the city's waste and rainwater. In only one of these ways, direct human intervention was needed. The first way to dispose of the water was for settlements created on a waterfront, such as a sea or a river. This is the case for various ancient cities such as Amphipolis, Dion, Pella, and Thasos. The case for Thasos is straightforward in that the city itself is built around the ancient port, and life centred around it, seen as a main avenue streaming from the Maritime gate to the Agora that was in proximity to the port.[188] This maritime gate also housed the conduit that collected all the waste and rainfall from the Agora and expelled it from the city.[189] This conduit led all water straight into the sea so the water could disperse it. Amphipolis, Dion and Pella had the same idea, but the closest water source was a river instead of the sea. Amphipolis sat on the side of the Strymon with their large water conduits set inside their fortifications facing the riverbed. This the trajectory of the wastewater would have had this river in mind so that it may flow south into the

[186] Kaifa, Karadedos 2013, 11.
[187] Ouellet 2019, 172.
[188] Grandjean 2000, 60.
[189] Grandjean, Wurch-Koželj, Kozelj 2011, 415.

Strymonic gulf. Pella had a branch of the Axios river flowing south of it, and Dion had the Baphryas river, which worked similarly. The rivers acted as the easiest vehicle that the Greeks could use to remove any unwanted water from their borders without becoming too stagnant and full of diseases. In other cities set on mountainsides, the slope of the mountain was taken advantage of. The ancient site of Kerdylion was set on top of the mountain of Kerdylion, with a clear view of the region. This may have been a defensive tactic, but it also gave a natural slope to all the wastewater dispelled from the fortifications, allowing it to run down the hill. Olynthus, too, had its city set upon a hill. From the western fortifications, a harsh slope would bring water down towards the small valley. Stagira's waste disposal system would have taken advantage of its hill and its position as a peninsula surrounded by water, thus having an outlet on each side of the city. The land's topography aided the ancient city in the disposal of its waste. This provided a solution that did not require consistent human intervention. This is not the case when the topography is flat outside the city's fortifications. The large water conduit which runs under the Gate of Silenus at Thasos is one such occasion. While the gate was at a higher elevation resulting from the numerous times it was raised, the land outside was considered relatively flat. If no action had been taken, the waste and rainwater would have been collected and provided an area full of disease and pungent odours. Therefore, the Thassians thought to dig a manmade canal right outside the southern side of the fortifications. This channel was built to continue the conduit via large rectangular blocks of marble with the same dimensions. Gradually it widened to 2.10m and was dug towards the west. Gneisses rubble, approximately 1.25m high and almost a meter wide, was placed on the sides to keep the shape of the conduit intact.[190] The presence of efforts to elongate the distance between stagnant and dirty waters and the city allows us to understand that ancient urban developers recognized that wastewater could be a hindrance. At times, it was possible to rid a city of this water by using their topography, but because of the threat it could cause, they did take action to rectify it.

[190] Grandjean, Wurch-Koželj, Kozelj 2011, 186.

6.0 Case Study of Ancient Argilos

As mentioned in the introduction to this dissertation, the ancient city of Argilos is where my interest in water management derived. Years of my involvement in the city's excavation allowed me ample time to understand their methods of ancient water management. To better comprehend the water systems in place in this city, this section will examine the site's structures and attempt to create a holistic picture of water management at Argilos using the previous chapters as support. This case study will begin its examination by mimicking the structure of the previous chapters. This begins with how fresh water was gathered before discussing the relationship between water evacuation and the city's grid plan, the use and disposal of water inside the household, and finally, the evacuation path of wastewater out of the city.

Regarding freshwater sources, two areas of interest provide evidence of how Argilos was supplied with water. As previously discussed, there is a well a few meters away from the front entrance of the Hellenistic mansion on the Acropolis. (Fig. 7) Approximately .70m in diameter, the well was lined with roughly worked stones. The depth is unknown, as excavations have yet to find the bottom of the well. As of the current excavations, this well is the only assured water source on the Acropolis. Therefore, there was a connection between that and the nearby mansion. This is further developed by the basin inside the mansion's central room. The mansion's lower floor was dedicated to producing olive oil, supported by the in-situ *trapetum* and other related structures needed to produce olive oil. The basin provides a closer water source for commercial activity than the well since water is an essential feature in the production process. This basin is often described as a cistern due to its position in what could have been the mansion's courtyard.[191] This is unlikely the case since the courtyard could not have been an open one. Two features suggest this. One is the lack of paving in the courtyard. Excavations have provided evidence that the occupation floor of the house is on beaten earth. In other courtyards, at Olynthus, Thassos, and other ancient cities, open courtyards are paved in stone. This provides an excellent surface to work on as well as a surface which is permeable to water. Should the courtyard be made of earth, the surface would have become muddy when rain fell through the open roof. This mud would create a slippery and messy environment unsuitable for producing olive oil. The second fact that disproves the theory is the lack of drains. At Olynthus, almost

[191] Ζάμπας, Δουδούμη, Θωμάς, Παυλίδης 2021. 363.

every courtyard had a water exit where the water would naturally gravitate in order to prevent accumulation. Therefore, the roof was most likely closed, and the Northeast structure in the central room was a basin. The well outside the mansion would provide fresh water for this basin and any water the family needed for their domestic needs. Another freshwater source that Argilos has is a shallow cistern found at House A in the Kamberidis sector.[192] This cistern was placed on the paved courtyard of the house and harvested the rainwater, similar to what was found in other ancient cities like Olynthus and Pella. These two are the only assured water sources found at Argilos. This may simply be due to not finding them yet, or it might be because there was a clear source in the area that was easily accessible, such as a stream or a spring that was active during that period. If there were an active well on the acropolis, it would have to mean that the water table rose on the hill of the acropolis before it descended into the sea. Nevertheless, until other evidence is found, there is little to discuss concerning the freshwater sources for the settlement of Argilos.

Argilos's urban plan followed the Hippodamian grid plan, where streets were set perpendicular to each other, creating city blocks. In the city's center, a single large flat avenue followed the hill from the Koutloudis sector to the Plateau before reaching the Acropolis. The smaller streets are made up of relatively small flat rocks and form a slight 'U' shape, with the rocks slightly sloped set nearest to the buildings. (Fig. 57) While they could be like that due to a shift in the streets due to the weight of the hill over time, it could equally be on purpose for water management. Throughout the site, various conduits and drains let out into the street, such as Q1, Q5, and S2. Thus, this curve to the streets allows waste and rainwater to collect in the center, not up against the sides of the buildings, and seep into the infrastructure and weaken it. As of yet, there is only one street where evidence of a built water conduit was located. (Fig. 58) The east-west street below building S has a built conduit on the southern part of the street. This conduit spans the length of the street and is approximately .30m wide. It is framed by vertical rocks on its northern side and a wall on its southern and is set lower than the street. This allows any water to flow to the lowest point onto the street, which would be the conduit and evacuate the water systematically. Despite the function being clear, there are some oddities to the conditions. The first is the lack of a bottom. Usually, there is a stone pavement to the bottom of the water conduits so that they can be easily cleaned and properly evacuate the water so that it does not

[192] Malamidou 2021, 317.

soak into the ground. There is a possibility that the excavations have yet to find the bottom of the channel, but it is already quite deep for a conduit when compared to other conduits, such as those at Olynthus. Another oddity is the lack of cover stones on the conduit. Flat cover stones were often placed on top to prevent people and large objects from filling in and obstructing the conduits. While it could be a coincidence that all the cover stones have disappeared over time or were reused, none have been recovered. The final peculiarity of this channel is its placement in the city. This street is on the lower slope of the Paliokastro hill, but on the slope, nonetheless. The slope indicates the water had some landscape to cover before it slowed and needed evacuation aid. Thus, there was no need to place this conduit here unless it was in an area with a high risk of flooding. Further excavations would produce accurate answers to these oddities. In other parts of the city, where the risk of flooding could be high, a new pattern appears in the formation of the streets. Instead of the stones lying flat, they were placed vertically to allow for gripping the rocks while walking. (Fig. 24) This can be seen in various places, such as below the spout on the north-south street in the Plateau, on some of the streets on the Koutloudis, as well as on the northern side of the south-eastern sector. These grips are placed in areas that often became slippery, such as significant slopes on streets, to prevent anyone from harming themselves.

Regarding public water works, Argilos has yet to find the agora, theatre, baths, or any other feature with specialized features. Instead, there is ample evidence for waterworks found in the domestic sphere.

Four sectors have evidence of drainage that drains wastewater into public streets. The Plateau sector has one instance of drainage set under the threshold of the western house along the north-south street.[193] This triangle spout is set inside the wall to evacuate any waste inside the house. The type of waste it would evacuate is yet to be uncovered, but spouts nearby thresholds, as seen at Olynthus, are often evacuation holes for rainwater in courtyards.[194] Since this area comprises larger households, one of which has a courtyard, it is not strange to think that this spout could have been used for this purpose. That courtyard is also particularly interesting since any liquid guided into it was insured its route by lead sealings in the stone so that no liquid could escape into the cracks. (Fig. 36)

[193] The house was set under the coordinates of 4016 under the wheeler system put in place at Argilos.
[194] As seen in house AIV9 or AV6 at Olynthus

Various buildings are set upon the continuation of the main avenue on the southeast slope sector, but Building E is the most interesting for water management. (Fig. 59) The function of Building E is relatively unknown. It had one long room in front with two rooms in back, the northwest room of interest. This room held a square hearth in the center with a metallurgic oven dating to the second half of the sixth century BCE in the southwestern part of the room and a bathtub in the southeast. This room seems to be a kitchen and bathroom area. The use of water was evident with the bathtub, which probably had water taken from the various *hydriae* found inside the room.[195] While baths and *hydriae* are also found elsewhere in Argilos, their proximity to a horizontal water outlet which lets out into an alley is interesting. This alley separates Building E from Building F, with the only outlet from Building E's kitchen area. While it acts as an area to remove any unwanted water and aerate the area, this alleyway acted as a private drainage ditch for this building since it was the only building known to have evacuated its water there.[196] This horizontal drain also promotes the importance of water in this room and the wealth of those who inhabited the space.

In the Koutloudis sector, water use and evacuation were seen in larger and smaller households. Q1 is one of the smaller houses with a similar spout to what was found in the Northwestern building in the Plateau sector. (Fig. 42, 45) Unlike the Plateau, excavations have revealed that its function was for the drainage of the bathtub set right beside it in the room's southwest corner. A series of flat rocks paved the area between the bathtub and the wall to prevent the floor from getting wet and to direct any wastewater toward the spout and out of the house. As previously explained, a large drainage opening is set in the eastern part of the southern wall of the tripartite house of Q5. (Fig. 43) This drain has two vertical rocks on its sides and a flat stone paving on its bottom and drains out into an east-west street. This created a .51m high and .38m wide opening for any drainage. While the room itself has yet to be excavated entirely, there are some assumptions that we can make. First, this drainage channel was used for the *louterion* found just north of the channel. These features, the *louterion* and channel, suggest that the small room they were found in was a bathroom. This is a common practice in other households, such as at Olynthus, where bathroom drains are common. It is unknown how deep the water channel reaches into the room, but it is possible to determine the estimated size by

195 Bonias, Perreault 2021, 20.
196 Bonias, Perreault 2021, 20.

studying the same type of channel in building S2. (Fig. 44) Similarly, the exterior of this channel is the same rectangular shape .41m high by .27m wide and drains onto a diagonal running street. The excavated portion inside depicts a paved path approximately 1 m long before it opens to a stone paved square area (.72 by 1.19m) with vertical stones on the two open sides to prevent spillage into the beaten earth flooring. Similar to how Q5 has the *louterion*, S2 had a stone stand for a vessel, such as a *louterion*, in the middle of the room. Since the *louterion* is often used as a wash basin, the frequent water use made the drainage channel necessary. The amount of space it takes up suggests the water's importance in this space. While there is no proof that Q5 has the same water system, its likeness suggests that the space in which the channel is located also had a heightened exposure to water, at the very least.

Another area where one can find drainage is in the southern wall of House A in the Kamberdis sector. (Fig. 6) Similar to Q5, the drainage channel is built into the bathroom wall. It is in the same form as in the channel at Q5 and S2, with two vertical stones onto a paved channel. In studying the room, this channel was for the purpose of evacuating the bathwater from the bathtub, set inside the ground, and any water that would have splashed onto the paved floor onto the east-west street outside.[197] The three cases from the Koutloudis sector portray the cases of drainage found in less wealthy homes or other buildings. This is an example of water management inside a wealthier home, where they had the time and money to pave their bathroom floor and create a solid drainage channel out of large solid stone.

In all of these cases of domestic drainage found at Argilos, certain assumptions can be made. The first is the case of drainage being placed in specific locations to drain unwanted water. Thus, there must always be a link between water inside the home and a drainage channel. The reverse is not valid. In the tripartite house of Q6, a bathtub was found just east of the primary threshold and before a small, enclosed room. (Fig. 61) As of current excavations, no drainage channel or pipe is found inside or in the outside wall of the house. Thus, any water used in the bath or elsewhere would have been removed by hand and thrown into the street. Although it is never guaranteed, wealthier households have more access to water and drainage than smaller households. They have the space and wealth to spend on the luxury of water management to make their lives easier.

[197] Malamidou 2021, 316.

To finish this study of the water management of Argilos, the waste and rainwater evacuation path must be examined. As previously mentioned, there are two ways that unwanted water was cast out from an ancient city. The first was through the fortifications through specialized openings or gateways. As of current excavations, there is only one sector at Argilos where the fortifications are present. This sector is on the city's southwest side in the National Road sector. [198] Unfortunately, the fortification does not provide evidence for any water evacuates. Despite this, while the city's main gate has yet to be found, the large avenue that runs throughout the site is the most significant indication of where this exit is located. While gates are generally for controlling traffic into and out of the city, they can also be used to evacuate unwanted water. As already discussed, the streets were used as conduits to channel waste and rainwater to the lowest part of the city. As of yet, this lower part of the city or the end of the avenue.[199] Since water seems to follow this avenue, it is possible that the unwanted waters would flow right out of the gate. While this is still speculation, there is an assured evacuation path from the city. Since this city is set on the seacoast, it must have had a harbour with direct access to the city for trade and other traffic. This provides a straightforward route for water rushing down the hill and a sure way of disposing of the wastewater. Once into the water, the current would carry the waste away with no effort by the Argilians.

Argilos was an important city in its region for many reasons. This study has highlighted its importance in the study of water management. It also shows how every ancient city gathers fresh and evacuates unwanted waters. These systems are too complex to summarize in only a few sentences. In the case of Argilos, various new innovative pieces of information can be discerned. Three types of water systems seem unique to Argilos: the vertical rocks placed in streets to act as grips, the arrangement of street sot have a U shape to act as conduits and drains in less wealthy households. In the cases pertaining to systems found not only at Argilos but also at other sites, the study of new cities allows for establishing patterns in different types of water management. This includes the relationships between spouts and drainage channels with the various activities inside the building, such as commercial, ritual, or domestic. This also involves the relationship between the wealthy and their water systems emphasized in Q1, Q5 and in House A of the Kamberidis sector.

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[198] Ouellet 2019, 134.
[199] As of the 2023 excavation.

7.0 Conclusions

The archeological record depicts the importance of water in everyday Greek life. Ordinary citizens can access water from their wells and cisterns or nearby fountain houses. The function of these waters has a variety of purposes, such as for drinking, cooking, bathing, and washing inside the household or for commercial production in shops or the courtyards of their homes. After they used the water, they had installations inside their home, which would guide the water outside their home to create a clean space. Those in charge of city organization had much to arrange to ensure the inhabitants had enough water and were not overrun with waste and flood water. While wells and cisterns can easily be private installations, aqueducts need more planning. Their water spring needs to be found, and the path back to the city layout and fluid so the water stays running. Once inside the city, the pipes were fitted under the streets and reached their destination, whether that being a *βαλανεια*, a fountain house, or a reservoir, all of which also needed to be built. Water management does not stop there, either. The waste from each household accumulates in the streets. Therefore, some sort of drainage needed to be established. This drainage also needs to handle the flood waters from thermal storms. These drains and streets must funnel these impure waters outside the city through the gate or create specific exits for water. Water management affected the lives of all city inhabitants and created a more accessible and comfortable environment for them. Through this study, several things can be understood.

As suggested in the second chapter, the Greeks understood that stagnant water was bad for their health and that pure water was beneficial. The amount of drainage found in public and domestic spaces supports this. The areas where water would accumulate within the home often had a drain. This was to provide the homeowners with a clean environment to live in. Other than stagnant water, water can turn earthen floors into mud. Since this would not be a prime environment to inhabit given the mess and foul odour, precautions were taken in the form of paved courtyards. This care for the state of their households is also suggested in houses that include the drainage channels into their households, such as at Olynthus, where even after its destruction, archeologists did not find the usual rubbish in those channels.[200] Sanitation and attention to the environment were considered to improve their health by installing and maintaining these constructions. The construction of drainage channels in the streets and bathing

[200] Cahill 2002, 118.

establishments also contributes to this. The effort taken to provide a clean environment suggests a standard of cleanliness that the Greeks attempted to maintain.

Another conclusion considered is the fundamental understanding of topography and the basics of gravity without calling it that. The Greeks constructed water systems with the intent that they could run independently without much effort. Using the slopes of hills provided momentum inside the pipes or conduits, which left the water to flow by itself. The city's inhabitants used the same strategy to maneuver fresh or impure water. The only difference is that this slope is often artificially made on flat terrain. Since these water systems are utilitarian, the goal of these systems is for them to work without constant interference outside general maintenance.

Water management was also a matter that was based on wealth. In larger households, there was the privatization of fresh water sources with wells, cisterns, and, in later periods, fountains, as seen in Pella and Olynthus. This privatization is also apparent in shops, like the Agora of Pella and the neighbourhood near the Gate of Silenus. The number of drainage channels and spouts found also increases depending on the size of the household or the importance of the building, as seen in the houses at Olynthus or in building V of the Palace of Pella. Wealth allows for more leisure time since they can dedicate tasks to others. This leisure time allows for the opportunity for luxury water management found in buildings such as the *gymnasium* and *βαλανεια* to be established and improved. This also allows the wealthy to enjoy the proximity of nearby water and increased drains. We start seeing the use of water and drainage where it does not necessarily need to be, such as in androns, which were rooms designed to promote the luxurious lifestyle of banqueting. Overall, the presence of a private water source or drainage is not a need. Some houses did not have either one, thus choosing to gather water from outside the household and remove the waste manually. With wealth, they can afford the convenience that private water sources or drainage channels provide, although it is a want rather than a need.

The tricky dating of water systems is due to the utility of the water systems. Conduits, pipes, and drains do not seem to have styles or patterns that can help to categorize them in terms of a time period. Like with the aqueduct of Olynthus, the dating of these water systems comes from their connection to other objects, ancient sources, or other factors. They are built to be used for their function, not for how they appear. The styles of these systems change depending on the materials that they have available and not always the period to which they belong. If the needs of these systems are not met, adjustments would be made, like siphons, to achieve the desired effect. Nonetheless, if there is no pressure to change these systems, there is no need to make modifications.

Although water management often follows a pattern, much remains to be uncovered. Each new city studied, such as Argilos, provides new information for the repertoire of water management found elsewhere in the ancient world. This dissertation was only a glimpse of the overall image of water management from select archeological sites. Even so, it provides the overall expectations of the water system types found in the urban environment. Whether these structures were made to aid the population in their water harvest or prevent waste and flood waters from hindering the settlement, they all aimed to support the cities to which they belong.

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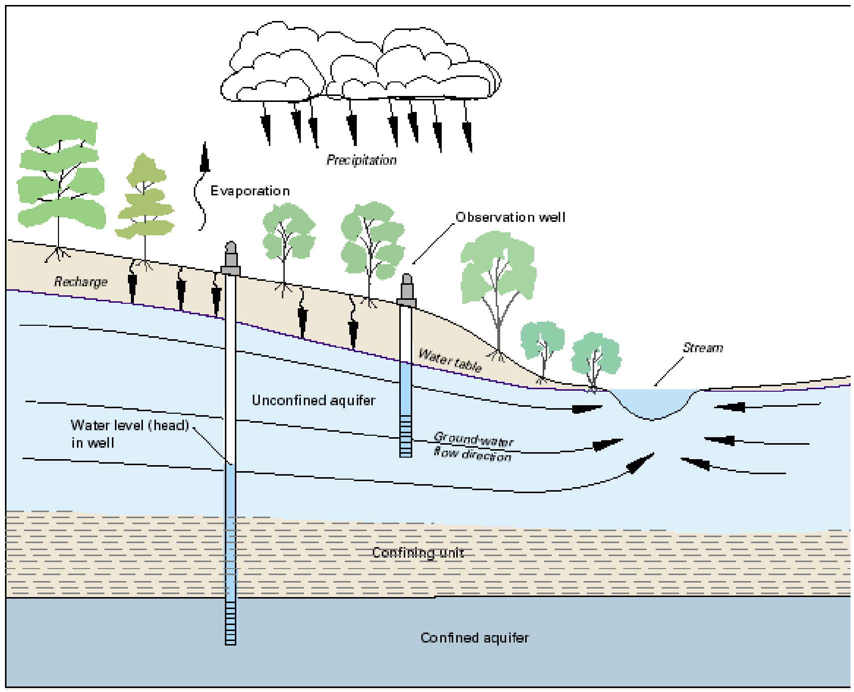
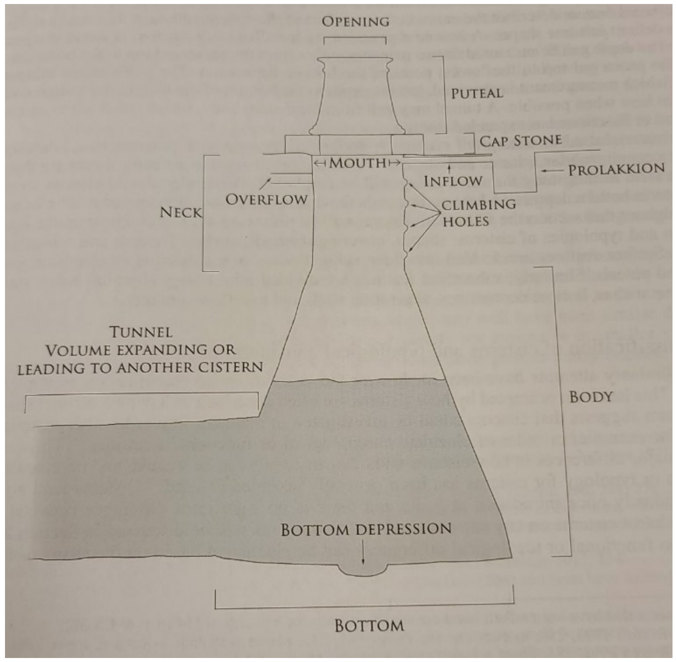
Plans



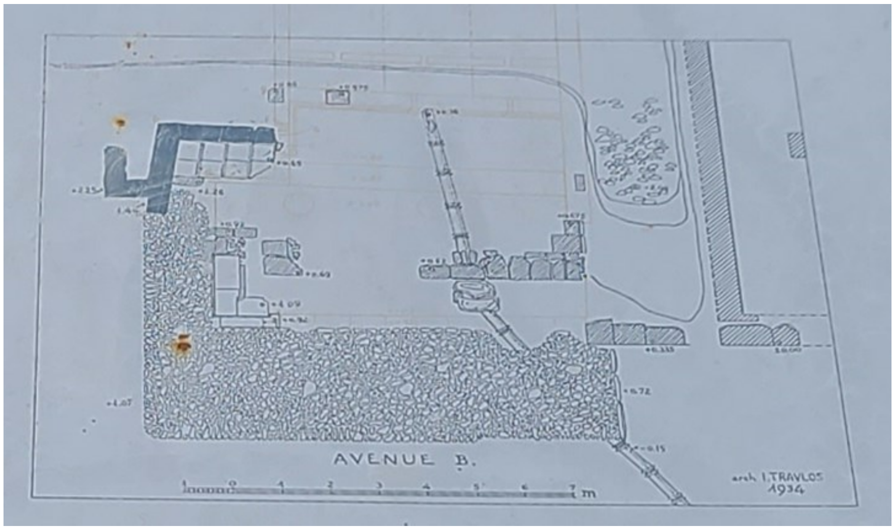
Plan 1- Typical water-ground water system (https://pubs.usgs.gov/circ/circ1217/html/boxa.html)

Plan 2- Layout of the Hellenistic mansion (blue arrow), the well (red arrow), and farmhouses, Acropolis, Argilos. (Mission archéologique gréco-canadienne d'Argilos)



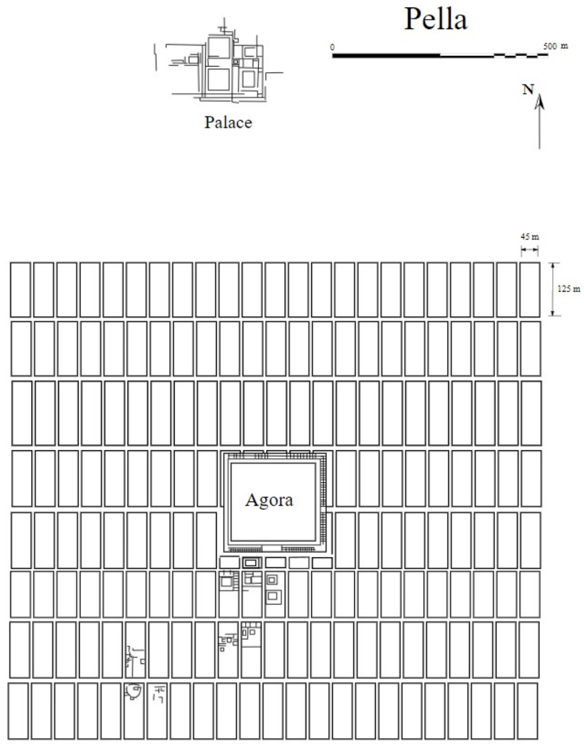
Plan 3- Sketch of a typical flask shape cistern.
(Patrik Klingborg, 2017, Figure 1)

Plan 4- Reconstruction of Block AV and the trajectory of the aqueduct, Northern Hill, Olynthus.
(Robbinson, *Olynthus XII*, figure 88.1)

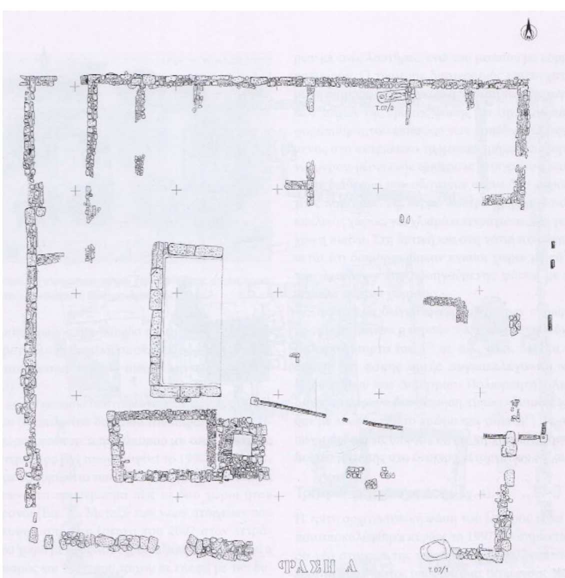


Plan 5- Plan of the fountain house, Northern Hill, Olynthus.
(Robbinson, *Olynthus XII*, figure 88.2)

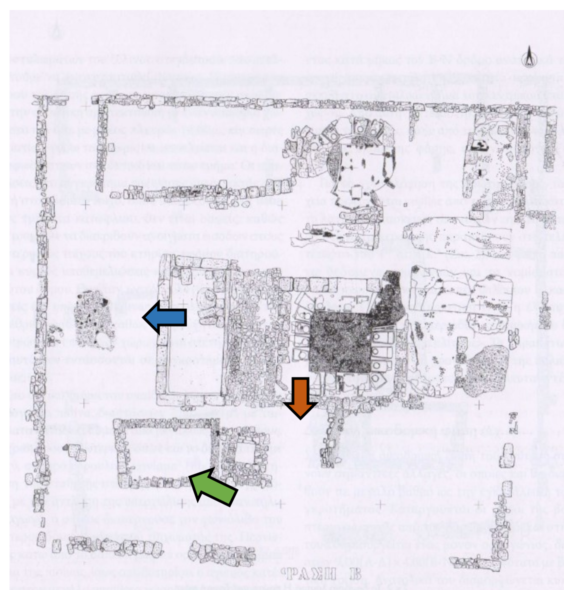
Plan 6- Urban plan of Olynthus. (Nicholas Cahill, 2000, Figure 1)



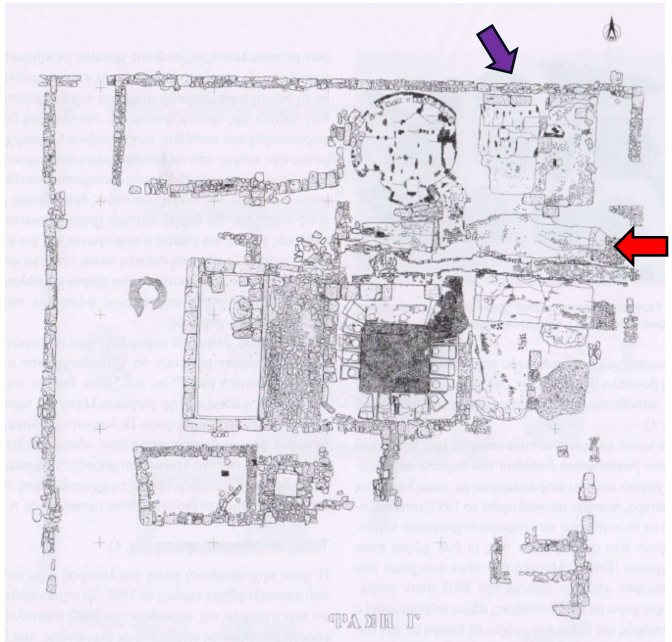
Plan 7- Urban plan of Pella



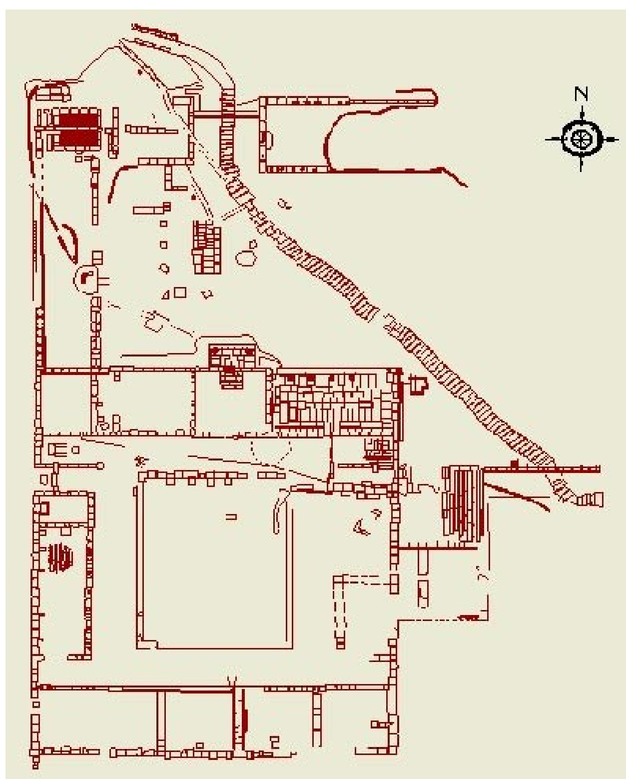
Plan 8- First phase of the *βαλανεια* of Pella
Blue-Swimming pool, Green-Cistern
Orange- Pipes. (Maria Lilimbaki-Akamati, Nikos Akamatis, 2007, plate 2)



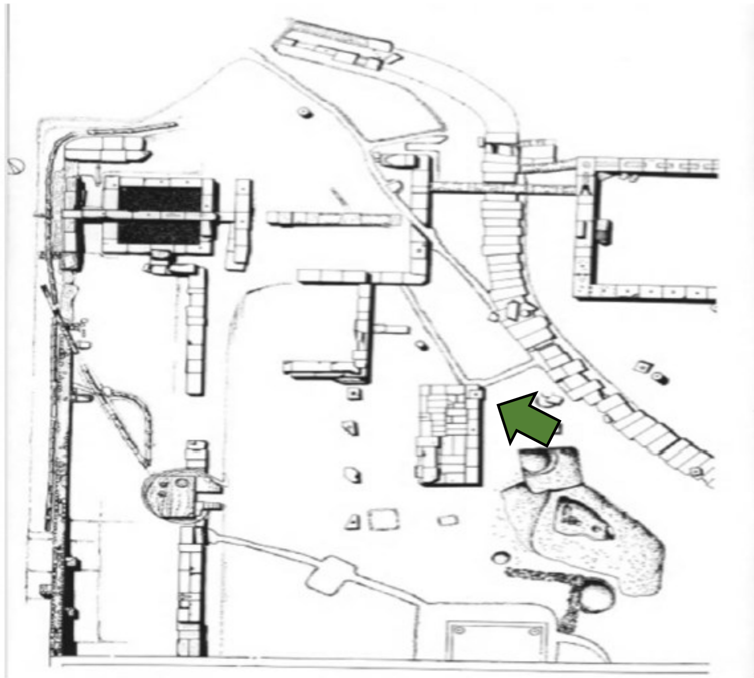
Plan 9- Second phase of the *βαλανεια* of Pella. Red- Hot room, Yellow- Tepid room (Maria Lilimbaki-Akamati, Nikos Akamatis, , 2007, plate 3)



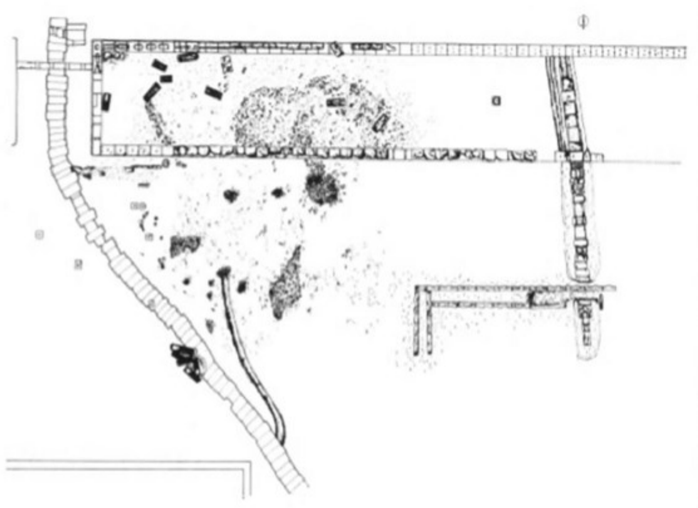
Plan 10- Third phase of the *βαλανεια* of Pella.
Red- Kiln, Purple- New hot room.
(Maria Lilimbaki-Akamati,
Nikos Akamatis, 2007, plate 4)



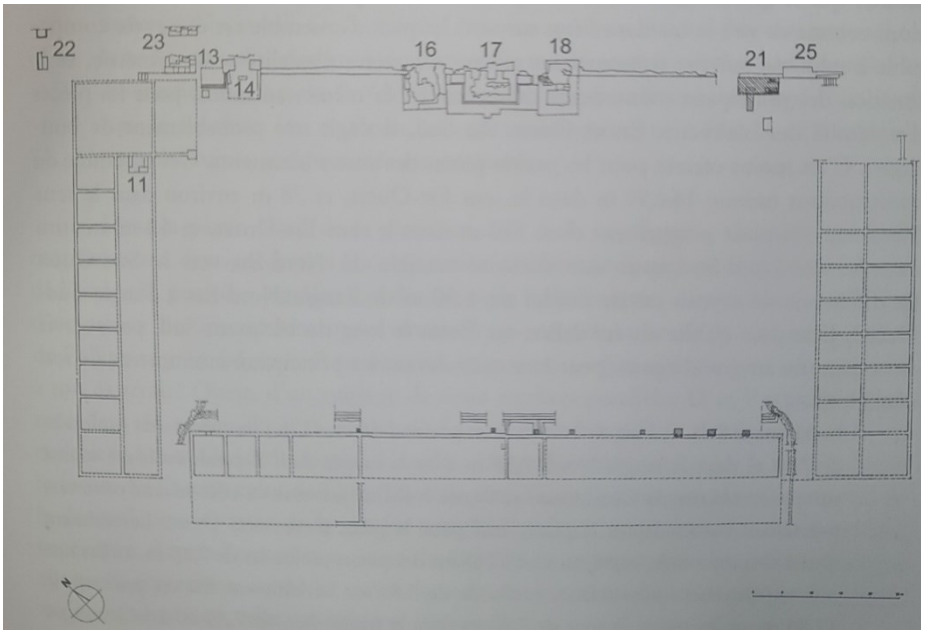
Plan 11- Plan of the *Gymnasium*, Amphipolis.
(http://www.macedonian-heritage.gr/HellenicMacedonia/en/img_C18a.html)



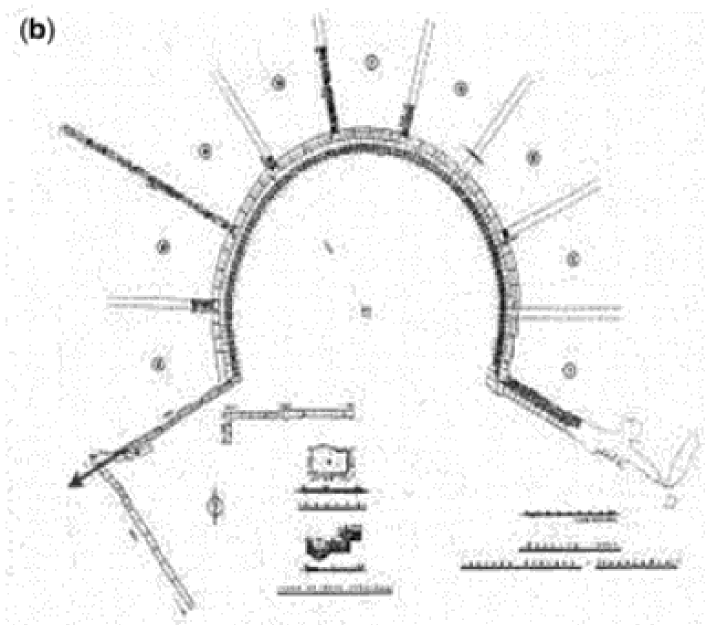
Plan 12- Plan of the northwest side of the *Gymnasium*.
Green- Alter with pipes (Lazaridou, 1988, 127)



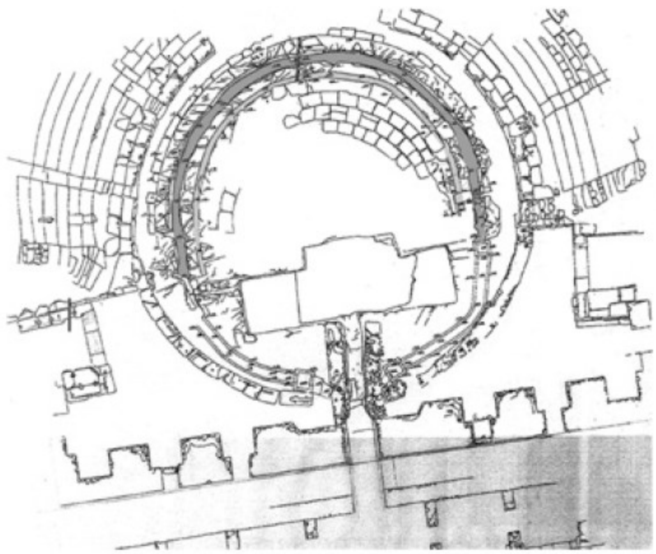
Plan 13- The sewer that crosses the *Xystos*, *Gymnasium*, Amphipolis.
(Lazaridou, 1988, 129)



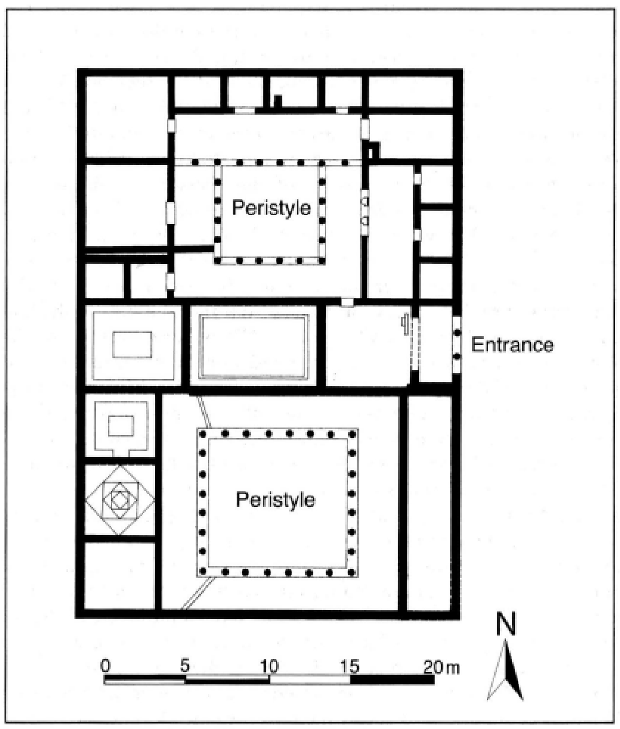
Plan 14- 1st phase of the forum at Philippi with straight water conduits.
(Sève, Michel., and Weber, Patrick, 2012, Fig.2)



Plan 15- Plan of the theatre at Aigai.
(Kaiafa, E., Papanikolaou, V. et als, 2014, 178)



Plan 16- Theatre of Philipi in the Hellenistic period
(Kaiafa, E., Papanikolaou, V. et als, 2014, 188)



Plan 17- Plan of the House of Dionysus, Pella.
(Lilimbaki-Akamati, Maria, Akamatis, Ioannia, et als, 2011, 114.)

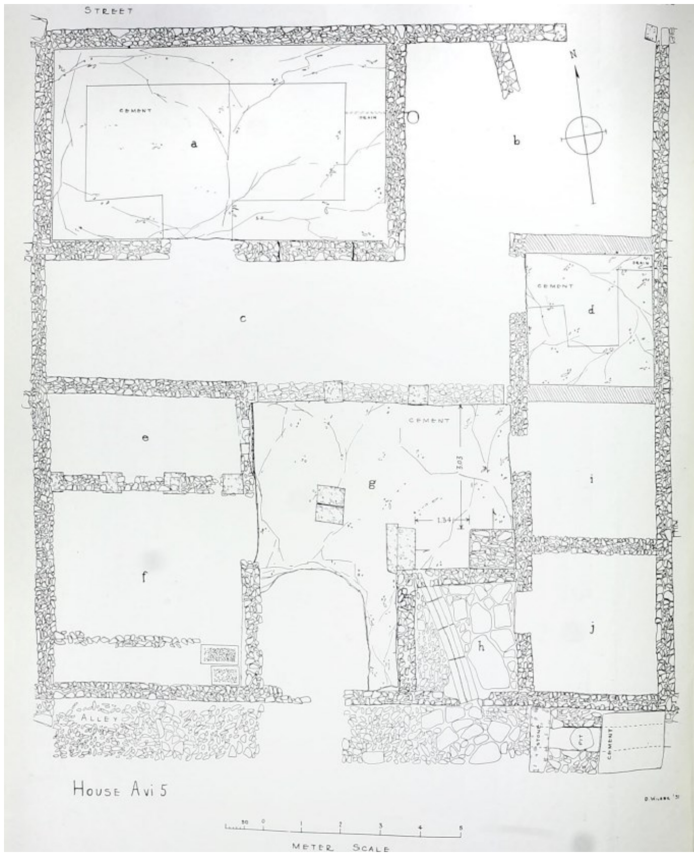


Plate 18- Plan of House AVI5 with a double Andron, Olynthus.
(Robbison, 1938)

Plates

Plate 1

Fig. 1-Terracotta cylindrical lining for well, Dion (Personal Archive)

Fig. 2- Puteal of a well (in situ), and a puteal of a cistern (broken), Akanthos (Personal Archive)

Fig. 3-Puteal with rope marks, Hellenistic house, Amphipolis (Personal Archive)

Fig. 4- Relief of Apollo and a Nymph with people presenting offerings, Passage of Theories, Thasos (Photo taken from Louvre website, Ma 696.1)

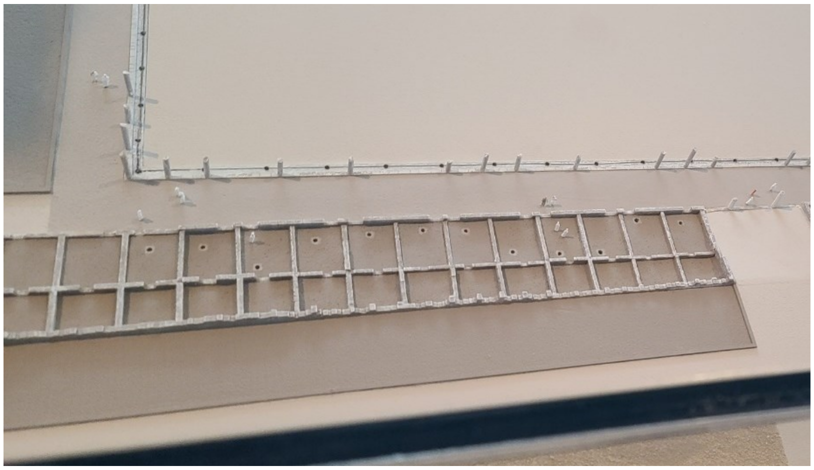


Fig. 5- Model [1:200] of the Southern part of the Eastern side of the Agora of Pella, Museum of Pella. (Personal Archive)

Fig. 6- West slope wear found inside a well in the Agora, Pella. (Personal Archive)

Fig. 7- Well outside the Hellenistic mansion, Argilos. (Personal Archive)

Fig. 8-Prolakkion from House Av5, Olynthus. (Personal Archive)

Fig. 9-Circular cistern lined with hydraulic mortar, Acropolis, Stagira. (Personal Archive)

Fig. 10-Above ground rectangular cisterns, Stagira. (Personal Archive)

Plate 4

Fig. 11- Clay pipes delivering water to tanks, Temple of Zeus Ammon, Aphytis. (Personal Archive)

Fig. 12- Fountain house with water aqueduct behind it, Aphytis. (Personal Archive)

Fig. 13- Reservoirs, *Gymnasium*, Amphipolis (Personal Archive)

Fig. 14- Swimming pool in the NE of building V, Palace complex, Pella. (Λιλιμπάκη-Ακαμάτη, Μαρία – Ακαμάτης, Ιωάννης Μ. 2004, fig. 31)

Fig. 15-Northeast Bathroom in the *Palaestra*, *Gymnasium*, Amphipolis. (Personal Archive)

Plate 6

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