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Mediterranean Archaeology and Archaeometry
Vol. 21, No 2, (2021), pp. 141-164
Open Access. Online & Print.

DOI: 10.5281/zenodo.4916489

THE CENTRAL WATER TUNNEL A NEW DISCOVERY AT UMM QAIS ARCHAEOLOGICAL SITE (JORDAN)

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Received: 19/04/2021
Accepted: 06/06/2021
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ABSTRACT

This study brought a new data with reference to the water system of Umm Qais during the Hellenistic and Roman periods. One of the most prominent characteristics of Umm Qais (Gadara) is the water supply system that produced a fine example of human ingenuity and skill to react with the available natural resources. The water supply system and its associated installations, such as cisterns, tunnels, channels and pools, collected and stored water from rainwater and the springs surrounding the site or far away from it. The discovered tunnel is located below the Hellenistic temple in the lower part of the city to the north of the Decumanus Maximus. The systematic excavation work sheds light on the nature of the water system and the nature of settlement in this area of the site. Excavation revealed that the hydraulic system consists of a central tunnel associated with several pipelines and cisterns to collect and store water. Confidently according to the nature of the tunnel system, we can assure that it was an important part of the public hydraulic supply system of the site. This discovery is unique in Jordan and the surrounding area.

KEYWORDS: Umm Qais, Water tunnel, Architecture, Roman, Hellenistic, Cistern; Heraclius' bath.

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1. INTRODUCTION

Jordan has been and still is one of the world's poorest countries in terms of water resources. Since early ages, the inhabitants of this part of the holy land realized the necessity of collecting rainwater. Yet it is one of the oldest countries in the world that was concerned with the collection and storing water, especially in the desert areas. Canals, dams, reservoirs and ponds, which were all used to collect and store rainwater in that area. (Helmes,1981:139)

Summer in Jordan is a dry season; for the inhabitants to survive, they have to establish a rainwater collecting system during the winter season. One of the oldest water supply systems of the whole world is the one found in Jawa. The system dates to the Early Bronze Age, about the 4th millennium B.C. The system consisted of channels, lakes, and dams. All system elements complement each other to collect and save water during the area's rainy season (Helmes, 1981:139).

During the classical period, the Greeks were the first to create water supply systems to collect rainwater for daily requirements. Several carved tunnels are found all over the Greek world. In Samos Island and Pergamon, city tunnels were dug into soft limestone and associated with shafted and sloped entrances. These tunnels were hidden to be far away from enemies during sieges (Landels, 1988:338).

Construction of the tunnels hydraulic system continued during the Roman period and developed to a higher level and became more sophisticated (Vitruvius,1960:227-228). Underground tunnels and aqueducts were carved and constructed to drive water from springs and lakes around the site. Furthermore, tunnels were preserved and cleaned by what Vitruvius called "Putei," which means sloped shafted entrances (Forbes, 1955:15). Arched bridges were built by stones, and bridged aqueduct above valleys associated with channels to supply cities with water (Vitruvius, 1960: 244-245).

The Romans managed to deal expertly with the topography of the different regions. One of their most significant accomplishments in this field was the constructed arched channel in the Spanish city of Ciqunia (Flon et al., 1988:170). Cisterns were carved in different shapes and sizes, 2-15m deep inside cities to collect and save drain water (Landels, 1988:343). In Athens, almost 440 cisterns connected by channels were found (Lange, 1968:5-11). The setting of Umm Qais is one of the most beautiful locations in Jordan. The Greeks and Romans managed to overcome the harsh terrain obstacles to maintain the city's water supply by digging wells, tunnels, and canals. Their solutions for these obstacles were innovative to secure the inhabitants of the city during dry seasons. Most of the previous studies dealt with talking about the city of Umm Qais in general and focusing on the area of the Acropolis without conducting organized scientific excavations in the central areas of the archaeological site.

The present research highlights these important facilities that are located on both sides of the main road called Al-Dekumanos Street and to reveal the hidden treasure. This study came to give a clear picture of the nature of the discovered water tunnel as well as to identify the nature of this tunnel in terms of functionality and access to the most important techniques that were used in digging it and knowing the nature of the materials used in the plaster and determine the extensions of this tunnel and its various dimensions.

One of the most important objectives of this study is to conduct an analytical architectural study of this tunnel to know its nature, its architectural function and the time period in which it was built, through drawings, plans, and photos, and to provide new archaeological, architectural and historical information about this important discovery. Also an attempt is made to establish the chronology of the construction of the tunnel and subsequent occupation of the surrounding associated excavated areas.

Another important issue is to study the relationship between the discovered tunnel and other tunnels for better understanding of the cisterns water supply system in the city.

As for the study area, it differs greatly from the desert areas in eastern Jordan, as its soil is suitable for cultivation (e.g. olive which is rain-fed agriculture that depends only on annual rainfall) and there are many springs but it is not sufficient to meet the needs of the local population, especially with large number of population. In the classical period, the Greeks and Romans thought about solving the problem of water shortage, by inventing a collection, storing and distributing water system. Because they depend on the collection of rainwater and the available spring water, then they dug reservoirs, wells and tunnels to transport water and distribute it throughout the cities in which they were residing, the most important of which is the water system followed in the archaeological city of Umm Qais (Obeidat and Miqdady ,2021; Shqiarat, 2019).

The study area is characterized by its fertility and suitable for agriculture, and the average rainfall in Umm Qais ranges from 326-770 mm. There are also many springs scattered around the city which encouraged most civilizations to build cities in that region, such as: Ain Umm Qais, Ain Al-Fakht, Ain Khenizira, Ain Magouq, Ain Al-Tabq, Ain Shehan, Ain Qart, Ain Hayya, Ain Al-Asal, Ain The soil, Ain Al-Harthin, Ain Al-Sheikh, Ain Al-Kharaj.

Prior to the Hellenistic period, the population was very small, and they depended on water sources close to the site, and the water available around the city of Umm Qais was sufficient to meet the needs of the population in that area. In the Hellenistic period, the population of Umm Qais was less than that of the Roman period. Later when the city's population increased, the city contained baths, temples, religious and civil facilities, so there was an urgent need for a precise water system that meets the various needs.

2. HISTORY OF THE SITE

Umm Qais (Ancient Gadara) is located about 30km northwest of Irbid city and 110km from the Jordanian capital of Amman. The site is situated on a plateau of 378 meters above sea level with steep slopes on three sides. The west slope faces Lake Tiberias, the south wadi al Arab, and the north the Yarmouk River, which leaves the eastern side the only possible access to the site (fig.1,2).

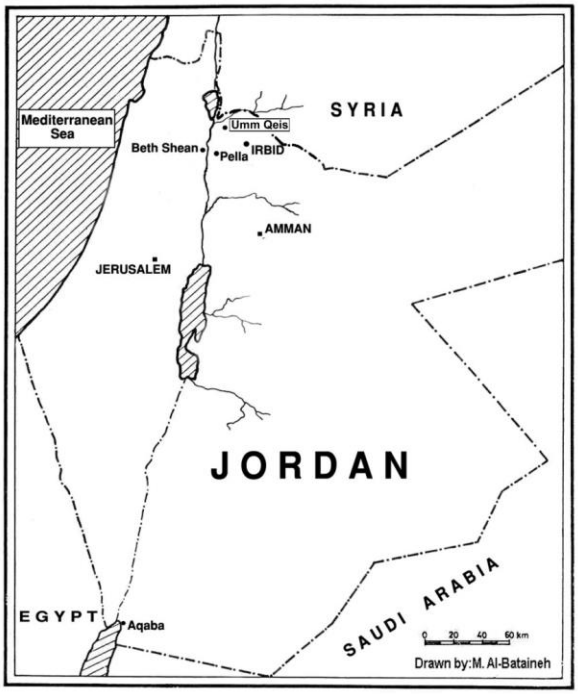


Figure 1: Jordan map representing the site of Umm Qais (Gadara) and Decapolis cities

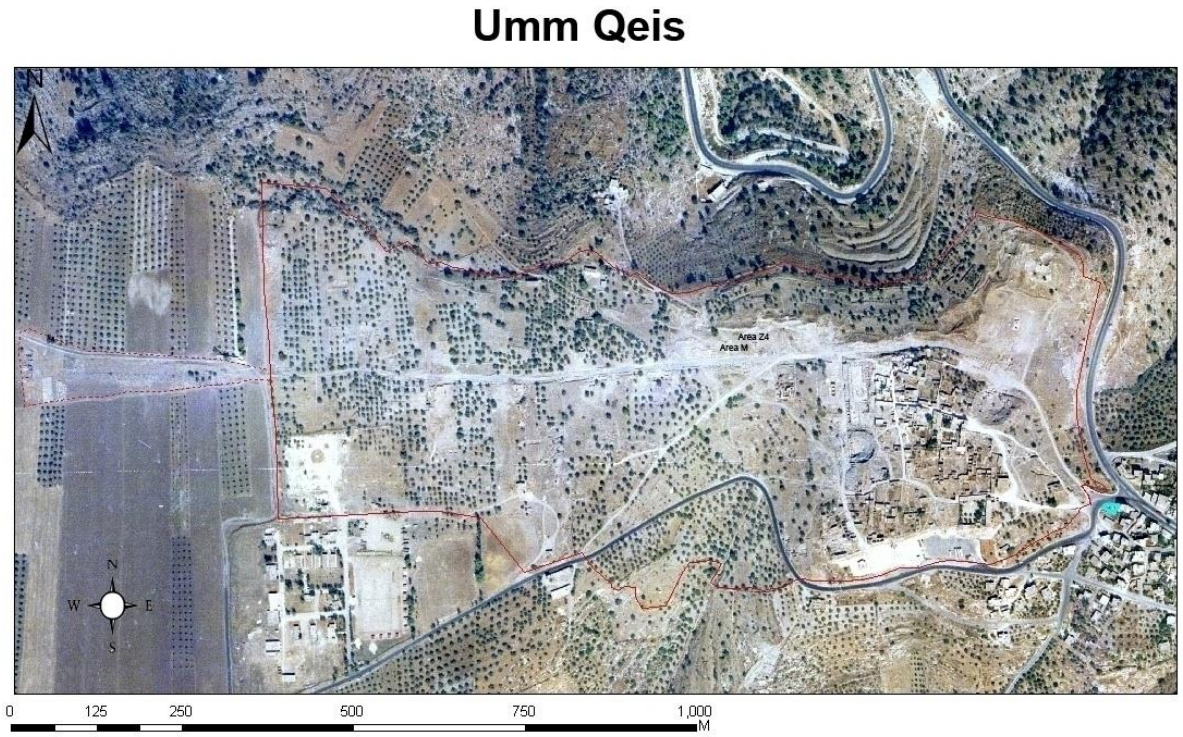


Figure 2: Arial photo showing the archaeological monuments at umm Qais (Shiyab, 2019).

In 1806, the German traveler Ulrich J. Setezen identified the ruins at Umm Qais as Gadara of the Decapolis and rediscovered site for the western world. The Levant was conquered by Alexander the Great in 332 B.C. Therefore, the area which is present Jordan came under Hellenistic domination. After Alexander's death in 323 B.C., his empire was divided among his successors. Gadara became part of the territory of the Ptolemies, an Egyptian dynasty. The Yarmouk River, immediately north of Gadara, was the Seleucid Empire's borderline, occupying Turkish, Syria territory.

Gadara first appears in the historical texts as a military citadel. In 218 B.C., the Seleucid King Antiochus III sieged Gadara and captured it to entry under the Seleucid Kingdom.

The Roman general Gnaeus Pompeius (Pompey) conquered the Levant in 63 B.C. The whole area, including Gadara, came under Roman domination. According to the historical sources, Pompey rebuilt Gadara damaged during the siege in 63 B.C. With other cities, Gadara formed the league of the 'Decapolis' 'The ten cities,' which was an association of at least ten officially independent cities that shared common cultural, political, and economic interests. They only had local independence while they were dependent upon the Roman Empire's politics, and they were linked with the Roman Provinces of Syria. Gadara flourished in the late first and particularly in the second century A.D., the period of flourishing period of Decapolis Cities, City plan, architectural buildings, and artistic features. The hot springs of Hammat Gadar in Yarmouk valley all refer to the new place of the city during the Roman Period. When Christianity became the official state religion in 391 A.D., Gadara entered the Byzantine period.

After the battles of Fihal (Tbaqat Fahal/Pella), in 635AD and the Battle of Yarmouk on 15 August 636 A.D., the region came under Islamic control. However, little information about the Islamic Period is still sparse because the site is still minimally unexcavated.

Fatal earthquakes severely damaged the site during the seventh and eighth centuries. During the Ottoman period, many stones were robbed out by local inhabitants who used them to build the village on top of Acropolis Hill (Browning, 1982, 18; Fitzgerald, 2004, 349-366; Peake, 1958, 23; Seetzen, 1859, 188-190).

3. SITE PLAN

The site's main feature is the paved and colonnaded main street (*Documanous Maximus*) with an east-west direction. At the same time, the Cardo with a north-south direction intersected with the *Documanous Maximus*. The latter divided the city into northern and southern sectors, on both of these sections building, and structures were erected. (Fig.3)

The city is characterized by an organized water supply system consisting of tunnels associated with channels and pipelines that supply all buildings and dwellings with freshwater (Weber, 1988:349-350, 1989:1-20).

Between 1974 and 1980, Vagner-Lux and Vriezen from the German Protestant Institute for Archaeology cooperated with the Department of Antiquities of Jordan carried out excavations, surveys, and plans for the site (Wagner-Lux and Vriezen, 1984: 87-90).

Guinee and Mulder draw a new plane for the site included *Documanous Maximus* and Cardo with detailed descriptions (Guinee and Mulder, 1996: 207).

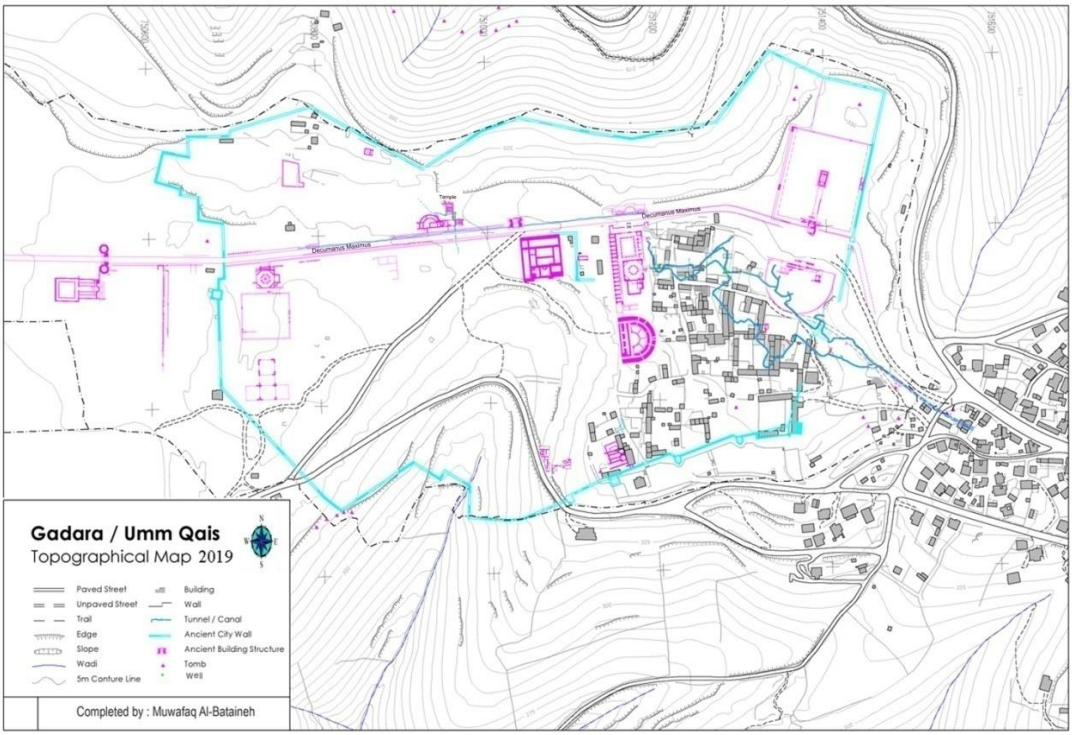


Figure 3: Topographic map showing most of the archaeological monuments and the excavation area at the site of umm Qais (Shiyab, 2019).

4. ARCHAEOLOGICAL EXCAVATIONS RELATED TO THE WATER SUPPLY SYSTEM OF UM QAIS

Several travellers and explorers visited the site of Umm Qais in the 19th century. Many of them recorded and documented the still standing architectural remains by drawing. The archaeological excavations in the site started in the 1930s by several international teams' incorporation with the General Department of Antiquities of Jordan (DoA). The excavations uncovered remains of architectural features that were dated to Roman, Byzantine, and Islamic periods. (Schumacher, 1890:45-82; ***Guinee and Mulder, 1992:288-289; 1996:207;*** Segal, 19944:46-47)

Mittman conducted his excavation in 1959 in the bath located in the northwest sector of the Ottoman Village, and he described and reported that the finds included mosaics and inscriptions (Mittman, 1970: 134-138).

The Danish archaeological excavation mission directed by Holm-Nielson excavated the Byzantine bath, situated west of the Acropolis Hill. The bath dated to the 4th century A.D. According to evidence, the bath was reused during the Umayyad period until destroyed by the fatal earth early in the eighth century A.D (Holm-Nielsen et al., 1986:2019-322) 1993.

Later on, in the 1980s, Weber exposed the remains of a Nymphaeum north of the colonnaded main street and dated it to the second century A.D. He also described the Byzantine and the Heracles baths. In his description, he reported that the Heracles bath contains several pools paved with mosaic floors dating to the 3rd century A.D. Weber also described and explained part of the water supply system of the city (Weber, 1990: 6-26; 1990a: 17-28). Kerner and Hoffman focused on the Hellenistic fortified city wall and associated towers, domestic quarters, water system, and Hippodromos (Kerner and Hoffman 1993:37, 359-363, 368). Kerner later studied the water supply system at the site in detail. She also made plans for the upper and lower water tunnels, focusing on the tunnels' water sources, especially Ayn Turab (Kerner, 1997: 287; 1997a: 268-269).

In 2013 Yarmouk University excavation team started digging in the Central Lower City in the north part of the main colonnaded street. Excavating in the previously mentioned part took place to uncover the archaeological remains and better understand their function. In the following seasons, excavation revealed the remains of a unique Hellenistic temple. In 2019, while attempting to clean the temple floor, a wellhead closed with a circular stone appeared. Therefore, the emphasis has been placed on knowing the nature of the archaeology beneath this circular cover. Post removal of the stone lid, it appeared that we were dealing with a huge part of the main water supply system of Gadara. Work started using all the necessary tools to uncover the mystery of these water installations. All excavation pieces of evidence assure that the remains belong to the Hellenistic and Roman periods. An abundant amount of full intact pottery pots and many sherds guarantee these dates (Shiyab 2013; 2014; 2015, P.1-21; 2016, p19-13; 2017-a, pp.137-148; 2017-b: 1-30; 2019 pp.100-115; Firas Alawneh, 2017).

5. WATER SOURCES IN UMM QAIS

The average rainfall in Umm Qais is 326-770mm, making the soil suitable for agricultural activities. (Beaumont, 1985:291-293; Water authority, 1980, 212-213)

Several water springs exist around the site of Umm Qais. They played a major role in the site settlement. These are, 'Ayn al Fakhet, 'Ayn Khanzereh, 'Ayn Maquq, 'Ayn Shyhann, 'Ayn al tabbaq, 'Ayn Qart, 'Ayn al 'assal, 'Ayn Turab, 'Ayn al Hartheen, 'Ayn al shaykh, 'Ayn khraj (Schumacher, 1890:84-113; Glueck, 1951, 142-143; ***Weber, 1991:228).***

These springs are located at a relatively lower elevation than the site, except 'Ayn et-Turab, situated 470m above sea level. It is considered the primary water supply source of the site.

Springs and basin water located far away from the site, such as springs of Qualbeh, Al turah, Dar'a, and Muzarib.

6. WATER SUPPLY SYSTEM IN UMM QAIS

The most important feature of this new discovery its location, which found at a depth of tens of meters. It consists of corridors that people can walk through. It contains water channels and transports water to the various facilities of the city. The workers in these tunnels with ease can clean and carry out all necessary maintenance jobs. Also it is characterized by the fact that it contains many entrances and the presence of stone valves and barriers through which it used forcefully for controlling and distributing water to the various city facilities. Which indicates that there is an authority that supervises the water system of the city and it became clear This is through the presence of places to control, control and maintain the water system responsible for fetching, collecting, storing and draining water in the important city of Umm Qais.

These new discoveries are considered among the rare discoveries in Jordan and the neighboring region, and that these discoveries are the first of their kind in the city of Umm Qais and are registered exclusively by Prof. Atef Al-Shayyab, director of archaeological excavations team, This site will greatly contribute to the process of interpreting the archaeological site of Umm Qais from a functional and architectural point of view, as well as revealing the water system and its

relationship with the rest of the archaeological parts of Umm Qais and other Decapolis cities.

The population of the site increased, and the city expanded during the Roman period. Therefore, additional sources of water were required. Cisterns were the only available source of water during the Hellenistic period. Many of the cisterns were found at the Acropolis Hill and dug into the bedrock of limestone under the surface.

According to Kerner 1997c, most of the surrounding water supply sources were located lower than the site. The only Ayn situated at a higher elevation is 'Ayn turab. The Ayn is located 12 km east of the site and is connected to an underground tunnel to bring water to the city (Kerner, 1997c:268)

In the Roman period, an arched bridged with an aqueduct of 60m long was constructed, attaching the eastern valley side with the Acropolis Hill. The aqueduct was built to facilitate the water flow to the site. A part of this aqueduct structure is still visible in situ on the eastern edge of Acropolis. The visible remains are 2.60m long and 4m in width, while other parts were destroyed by earthquakes and the modern roads of umm Qais' village. The aqueduct bridge looks similar to the known one in Quasareah Martima (Kerner, 1997a: 285-286). Right up to today, the remains of the water distribution control system are visible on the aqueduct's edge (Sleuce stone). Those remains suggest the existence of an official water management authority. The system does look very similar to the one located in Abila of the Decapolis (Mare, 1996: 262). The Romans were famous for constructing bridged aqueduct systems. A well-known example of such a construction is the one found in Italy named Marcia Bridge. That aqueduct bridge used to supply Rome with water. It consists of an underground tunnel 80m long connected with a bridged aqueduct 686m long. The bridge was constructed between 140-144 A.D. Another example of a bridged aqueduct is Claudia's canal. It is 53km long and brings water from a faraway spring to Rome **(**Nash,1981: 37-84; Landels,1988:340-341**).**

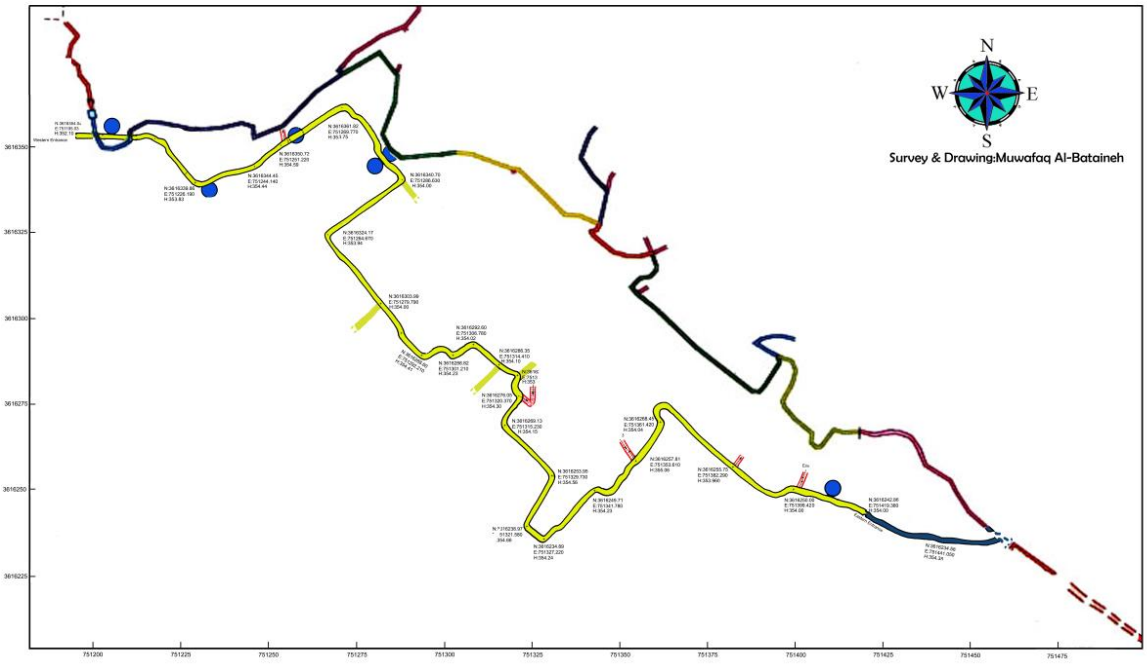


Figure 4: The lower and upper tunnel plans at the site of Umm Qais (Shiyab, 2019).

Umm Qais water system consists of many reservoirs, circular ponds, and wells carved in the rock take the shape of pears. These water installations are linked to the system of tunnels and channels for the distribution, storage and use of water when needed. Other parts were built of stones to distribute water to all parts of the city.

And for the first time, a water tunnel dating back to the Hellenistic Roman era was discovered, and its cabin is still in excellent condition. This tunnel consists of a group of deep wells, which dated to the Hellenistic period, the height of each of them is estimated at about (15) m, starting from the upper narrow hole (a well bead) to the bottom of the well.

Roman carved underground tunnels to supply and distribute water to the city of Umm Qais monuments (Fig 4). Underground water tunnels were carved in limestone rocks and followed the contour levels; on average, these tunnels reached about 20m deep. These tunnels were found in the lower central city at different elevations. Therefore, they were called Lower and Upper Tunnels:

6.1 The Lower Tunnel

The tunnel was constructed in Hadrian's period at about 130 A.D. The construction of the tunnel took around 80 years of work. The lower tunnel is connected with the Far'un canal that leads the water from 'Ayn turab to the site. Surveys proved that tunnels extended throughout northern Jordan up to Mozarib Lake. The lake can hold about 1 km^3 of water. It is considered one of the largest lakes in the area. It is located west of the city of Dar'a in the Syrian territory (Kerner, 1997a:286).

The aqueduct of Umm Qais consists of two walls and a paved floor with small-size plastered stones. The aqueduct slopes down to the west connecting the lower tunnel parallel of the upper tunnel under the Acropolis Hill and Ottoman village. The lower tunnel was carved earlier than the upper tunnel. Both were cut into the limestone rocks and plastered. The marks of running water are still visible to the naked eye, which proves that it was intensively functioning. Upon the water's arrival via the channel, it was led to a room to save and control. Mostly, the space allows water to be driven to a lower or a higher level. The chamber has a shaft entrance to control the amount of preserved water and allow precipitation of all dirt to secure clean water. A tunnel extends about 25m long towards the north, connecting the room with a 5m deep cistern. Close to the terrace church's eastern wall, the lower tunnel terminates (Kerner and Hoffman, 1993:370).

The lower tunnel's door was blocked near the eastern wall of the Basilica by plastered basalt blocks to control water. The blocking is associated with three-hole water pipes (dim. 12cm) that supply all connected channels by water. The Lower Tunnel features a Casttelum—a distribution chamber lined with ceramic and outfitted with lead pipes (Plomer, 1973:25-28). The channels branch on both sides of the main street:

6.1.1 First Branch

It runs to the northeast Byzantine terrace church's corner, then bending to the west along the church's northern side. The water flows down to a T-shaped channel toward the main street to supply the north's intersecting channels (Kerner,1997a:286).

6.1.2 Second Branch

It runs beside the main street from the south, branching from the T-shaped channel. This branch supplies the channels associated with the ceramic pipes located in the Cardo (Wagner-lux and Vriezen,1982:157). Furthermore, this branch is the main line that supplies several buildings in the surrounding area, such as the western theater, vaulted shops, and byzantine bath (Holm-Nielsen et al., 1993:156; Wagner-lux and Vriezen,1982:156). The lower tunnel is older than the upper. Two layers of hydraulic cement plaster the interior of the tunnel to preserve water.

6.2 The Upper Tunnel

It still remains unclear that the upper tunnel considered a part of the water supply system in the site for the following reasons:

1-The channel connected with the upper tunnels were never covered by slab stones, which expose them to dirt and pollution.

2-The channels originally connected with the upper tunnels were not deep enough and not plastered.

3-Water was never carried through the channel connected with the Sleuse stone near the aqueducts because its level is lower than the upper channel water.

4- The work in these tunnels never finished—only the first 50 meters of the floor was leveled on the eastern end.

5- The floor of this tunnel is partially leveled. The eastern part is lower than the western part, about 60 cm, which means that water cannot run through the upper tunnel.

6-The walls of the upper tunnels are not plastered.

7-There is no evidence of usage—its western end was cut as a cave looking on the eastern wall of the Basilica (Kerner, 1991 a: 227; 1992: 412; 1994:56-57; 1997a:285-286).

6.3 Pharaoh's Channel

John Got Watztein was the first traveler who gave the tunnel this name in 1858. He was influenced by Umm Qais' inhabitants, who believed that Egypt's phar'oun built this tunnel. However, the Far'oun's tunnel is running from the Village of Da'al southern Damascus about 60km through Dar'a. Then it crosses the Jordanian border through at-Tura village towards ash-Shalaleh valley. The tunnel extends to the west from ash-Shalaleh valley crossing all villages and valleys until it reaches Umm Qais' site (Weber,1991b:127).

Schumacher 1890 visited the site of Umm Qais. He described the tunnel in his writings as a single primary tunnel that starts from 'Ayn turab and goes up to the bridged aqueduct on the eastern edge of Acropolis Hill of the site. He also wrote about the two main branches of the tunnel, the lower and upper (Schumacher, 1890:78).

6.4 The Central Water Tunnel

During the excavation seasons of (2018/2019) at the Hellenistic temple in area Z4, several stratums were removed to uncover the temple floor. After the

removal of the Byzantine stratum, a well-preserved wall appeared. According to the context findings, pottery sherds, bone, and glass fragments, the wall dates to the Roman period. When all debris was finally removed, it became clear that the wall is one of the temple's courtyard walls. Therefore, excavation concentrated on the limestone wall that runs from the north to the south of the main colonnaded street. The wall is located in squares G17, G17, G18, and G19 (fig.5).

The most significant discovery was in square G17, a solid arch built with well-cut limestones in the square's eastern part. All the findings associated with the arch date to the Late Roman Period (Fig.6, 7, 8).

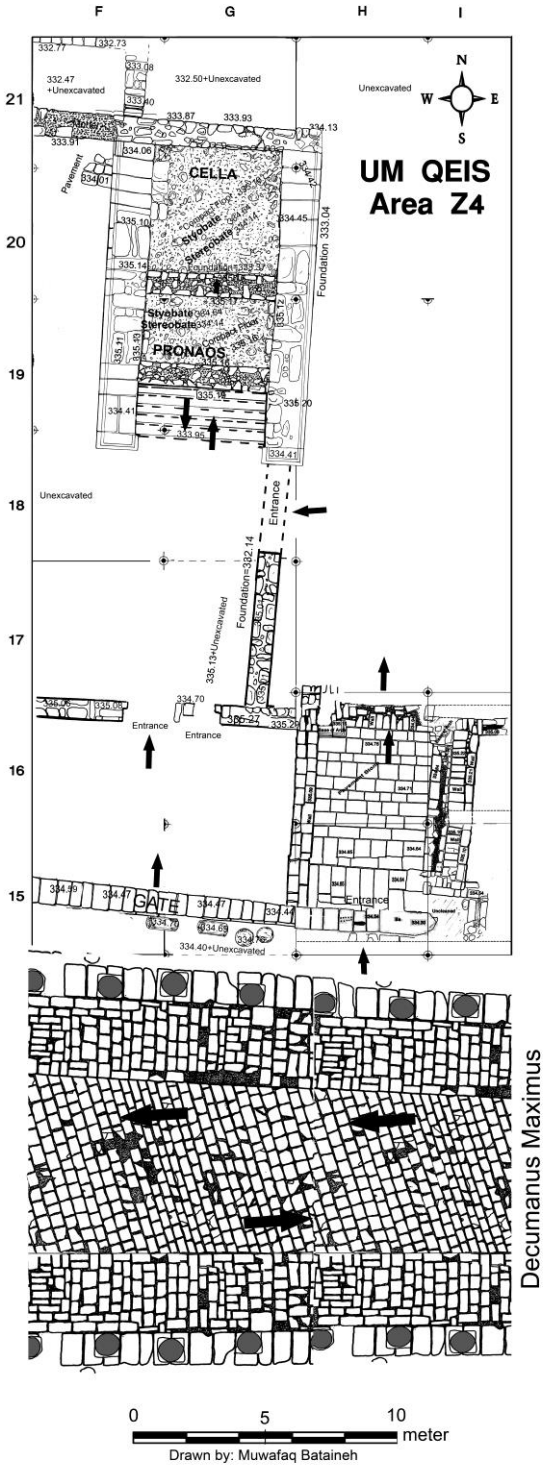


Figure 5: Plan of the different sections of area Z4 above the excavated water tunnel (Shiyab, 2019).

Figure 6: A. square G17 showing the arch. B. the wellhead of the well No. C

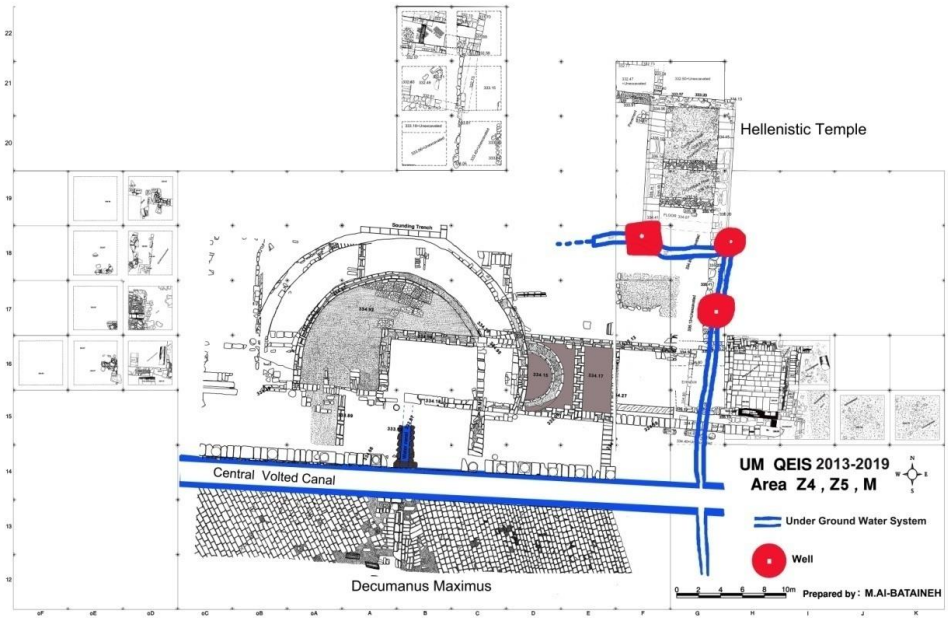


Figure 7: Plan showing the archaeological excavations (area Z4, Z5, M) in the central part of umm Qais (Shiyab, 2019).

Figure 8: General view of the excavated area.

6.5 Cistern

Three main cisterns were uncovered during excavation. After the debris was removed, it appeared that all of them are similar in shapes, and techniques.

6.5.1 Cistern C

It is a bottle shape cistern; its total inner measurements are 7.15m and 10m deep. The cistern mouth was a carved limestone slab measuring 2.50m connected with the surface by a built cistern neck about 1.70m diameter up to the soil's surface (Fig. 9). The mouth of the cistern was covered by basalt block (Mounting stone) dating to the Hellenistic period according to the archaeological remains (Fig.10, 11,12)

At the bottom of this cistern, tunnels were detected. One runs to the north to cistern B located under the Hellenistic temple, while the other tunnel runs to the south connecting with the arched drainage tunnel located under the northern part of the main street *Decumanous Maximus*.

Close inspection of the cistern showed that two plaster layers cover the whole interior. The first layer is coarse aggregate plaster, and the second is fine. It was concluded, following naked eye examination, that it is hydraulic cement. Further scientific analysis will come out when ready concerning the type of the plaster used in the cistern.

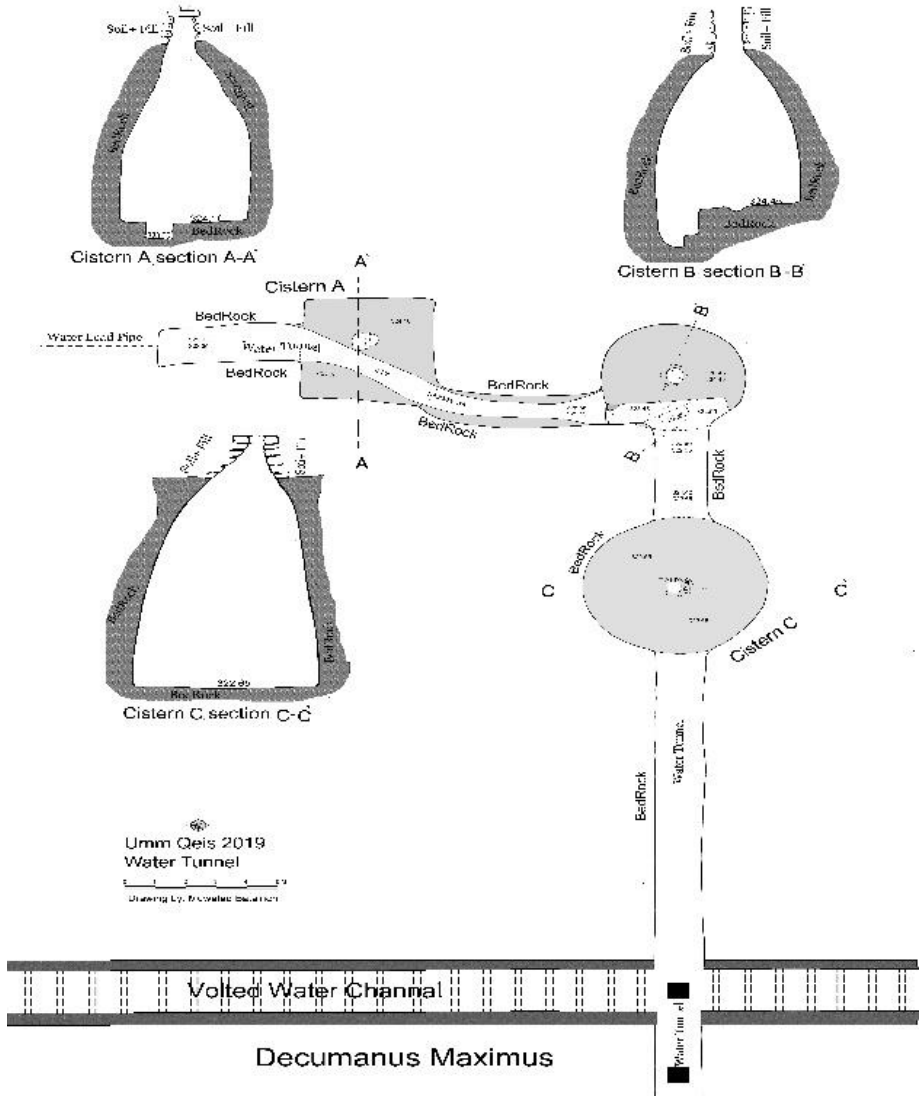


Figure 9: The hydraulic system general plan with cross sections of the wells (Shiyab, 2019).

Figure 10: A&B&C&D the nick of well C. E.&F removing dumb from well C in square G17.

Figure 11: A&B the Tunnel under excavation from well C to the vaulted tunnel.

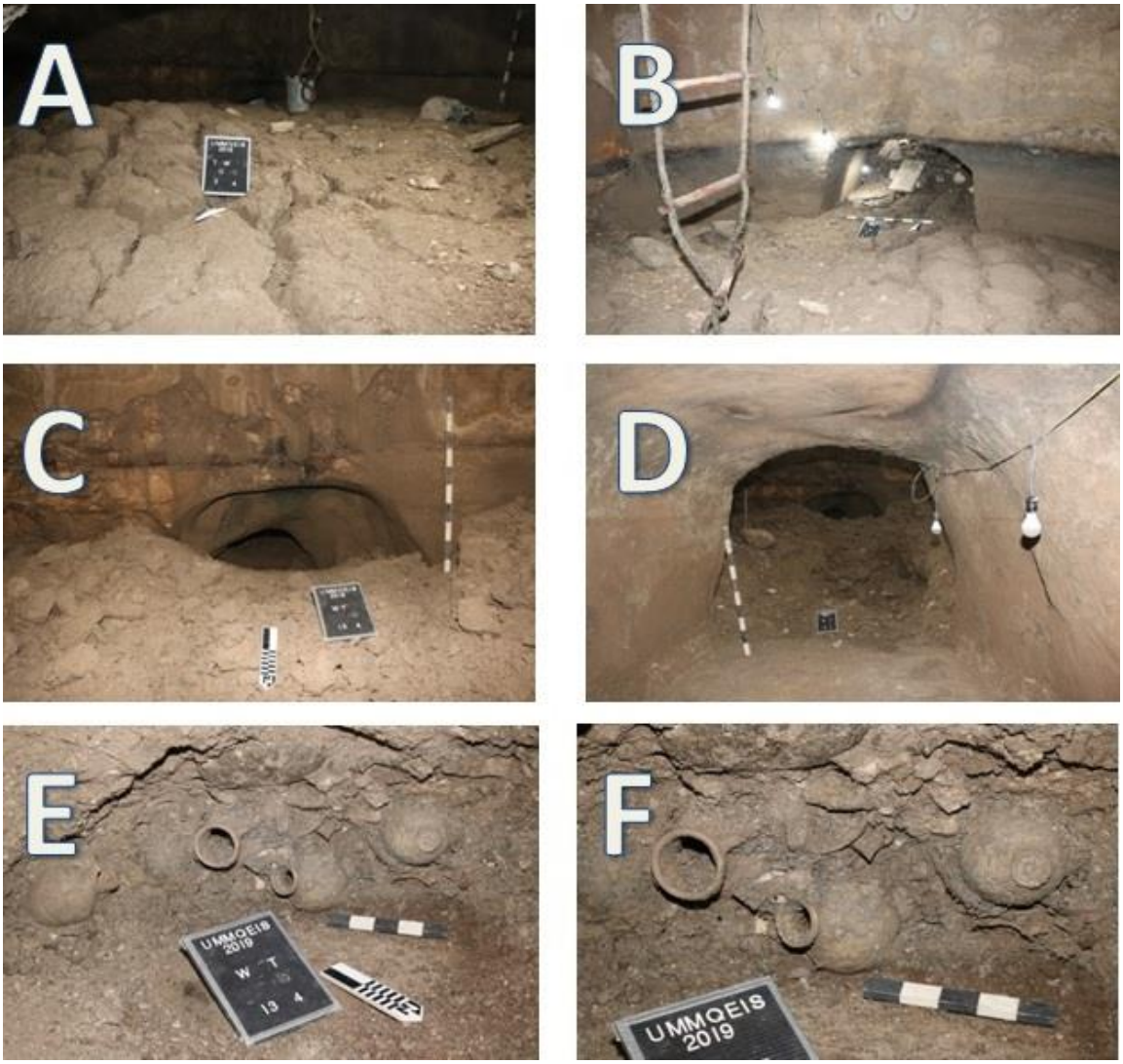


Figure 12: A&B the dumb over the floor of well C. C&D. The openning the tunnel that extend twards the south to the vaulted water tunnel. E&F. Pottery artifacts in between the dumb layers in well C.

6.5.2 Cistern B

It is a bottle shape as well (fig.13). The total inner measurement of the cistern is 5m at the bottom and 7m deep. While moving up, it becomes narrower until it connects with the surface by a built cistern neck measures (1x2 m) connected to the cistern mouth that measures 1.70 m in diameter. The cistern's mouth was covered by a basalt block as well (Mounting stone) dated to the Hellenistic period.

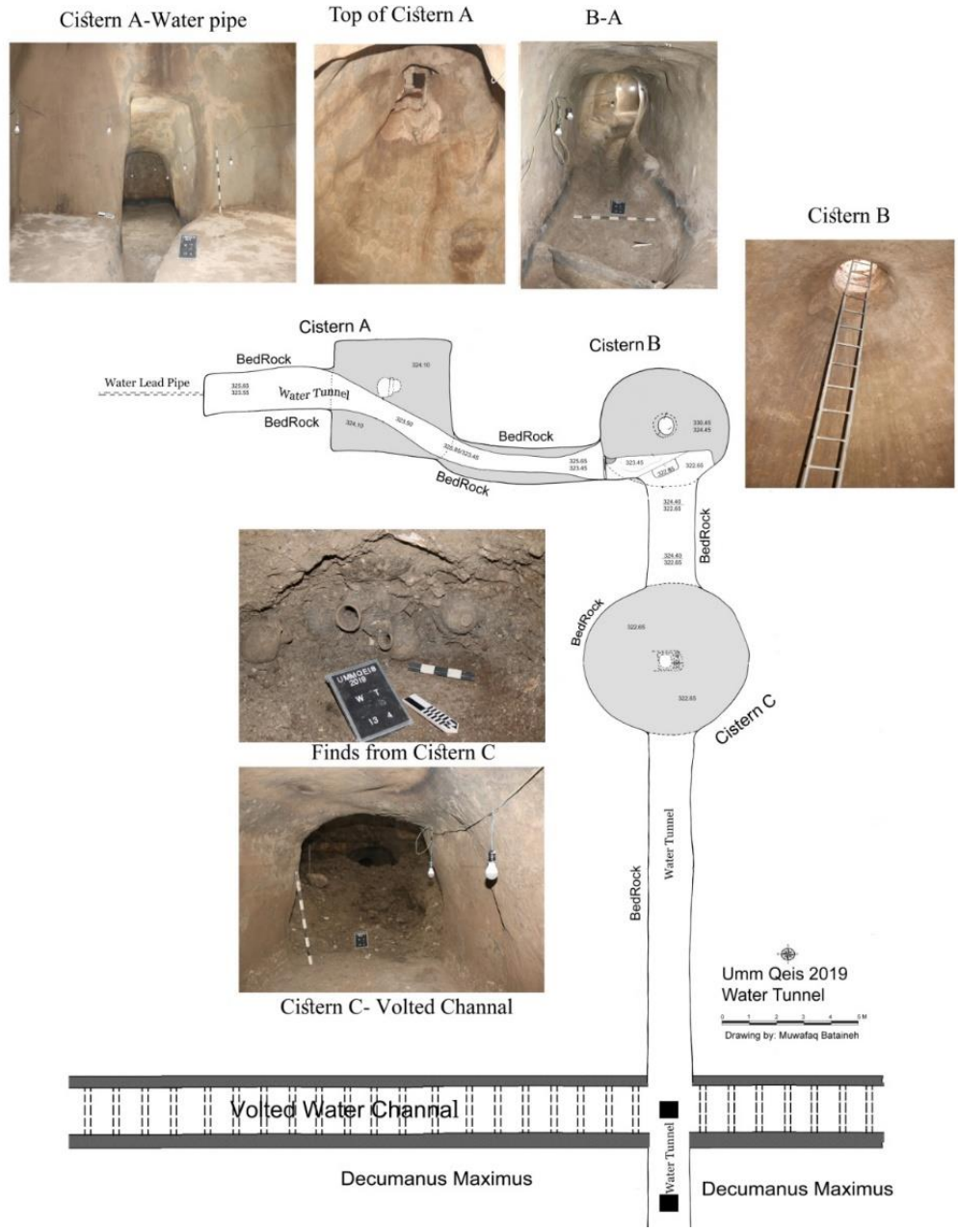


Figure 13: The hydraulic system general plan with illustrative photos (Shiyab, 2019)

Water tunnels were exposed at the bottom of this cistern as well. A channeled tunnel was found running to the west connecting with cistern A (Fig.14, 15).

The cistern's last visible stone is the mouth cut into the rock, measuring 1.67 m (diameter). The cistern's mouth was closed with basalt block during the Hellenistic period based on the dated finds. The bottom tunnels were found containing channels cut into the floor level running to the west where cistern B is located, while the others run south to connect cistern C.

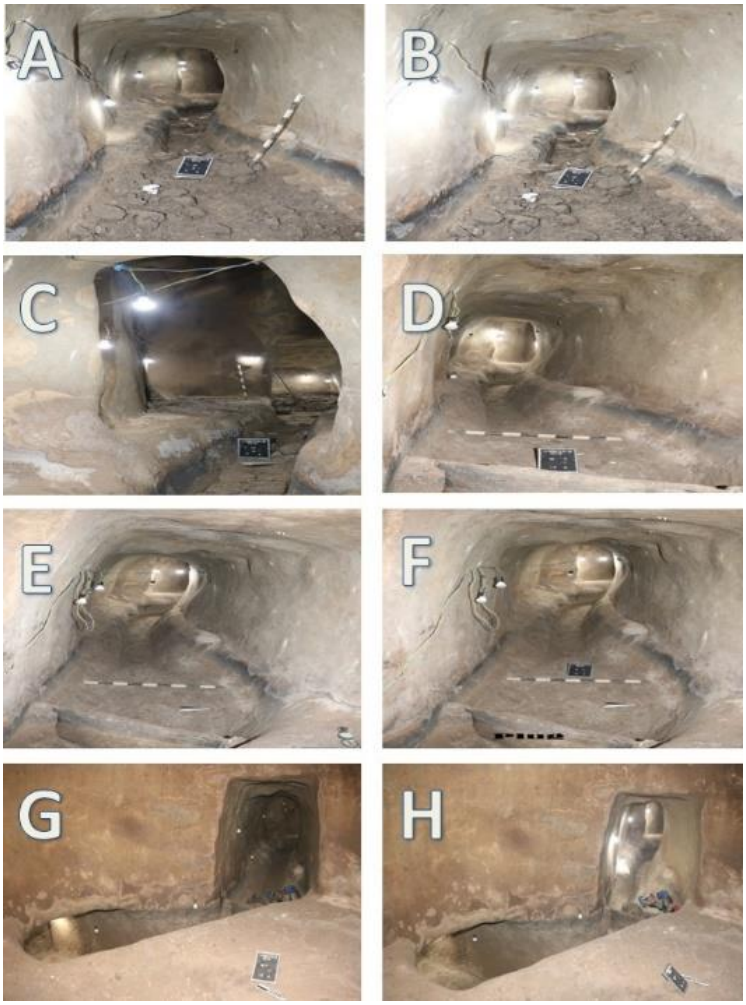


Figure 14: A&B the floor of the tunnel from B to A before removing the archaeological dumb. C&D&E&F. the clean tunnel after removal of the archaeological dumb and the appearance of the channel. G&H. The clean floor of B representing the tunnel and the channel toward well A.

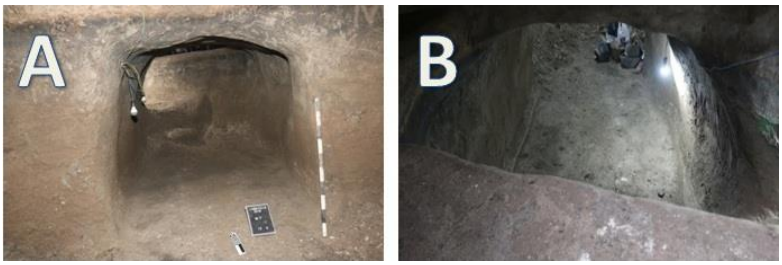


Figure 15: A&B. the extension of the tunnel from well B to C from opposite directions.

Several fallen stones and blocks were found that seemed to belong to the Hellenistic temple. However, the finds from this square were dated to the Roman, Byzantine, and Islamic periods (Fig.16). Based on the preliminary pottery readings, this square's earlier level dated to the Late Hellenistic period. Cistern B connected with a tunnel that contained a water channel. Sleuse stone was found running to the west to connect with cistern A (Fig.17)

Figure16: A&B&C&D. Sq. H18 after removal of all the settlements layers until the uncovering the mouth of the well B. E&F. presenting the depth and shape of the well B. G. the processes of removing archaeological dumb by barrel hugged by winch (crane). H. the floor of well B after removal of all the archaeological dumb.

Figure 17: A. the floor of B showing the tunnel and channel towards well A. B. the floor of B showing the tunnel toward C.

6.5.3 Cistern A

Located north of cistern C, Cistern A is a bottle-shaped cistern. Its inner measurements are 5m wide and 9m deep. In the bottom of this cistern, a 0.50 X 0.50 hole was found. The cistern mouth is cut into the rock and measures 1m in diameter, and a built neck over it up to the surface measures (1x2m). According to archaeological remains, the mouth of the cistern was covered by a basalt block (Mounting stone) dated to the Hellenistic period. The bottom of cistern A contained a channel directed to the west where the Heracles path is located (Fig.18).

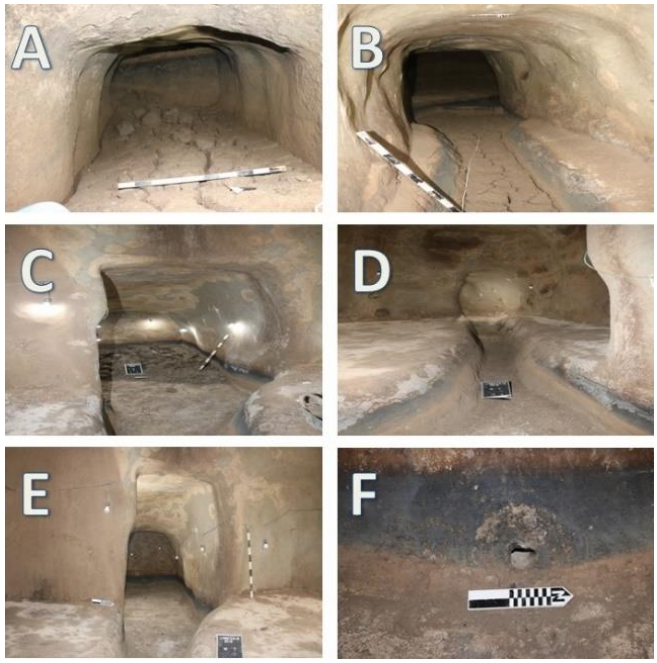


Figure 18: A&B&C. The tunnel with archaeological dumb which extends from well A toward the closed tunnel ending. the closing wall has a water lead pipe in the bottom of the closing wall. D&E. The appearance of a channel after excavation and removing all archaeological remains in the tunnel. F. The closing wall with the lead pipe at the bottom.

6.6 The Discovered Tunnels and Channels (Fig.7, 8)

The channeled tunnel in cistern A runs to the west until a blockage wall. At the bottom of this blockage wall, a lead pipe was placed (fig.19). This lead pipe probably carried water out to the pools located west of the Hellenistic temple and to Heraclius' bath.

The southern tunnel, associated with cistern C, is connected with the arched drainage tunnel under the sidewalk north of Main Street. Only forty meters of this central tunnel was exposed. There is a relation between this tunnel and the arched tunnel under the northern sidewalk that runs from east to west along Main Street. No doubt, this system is associated with the main lower tunnel located north of Acropolis Hill (figs 25).

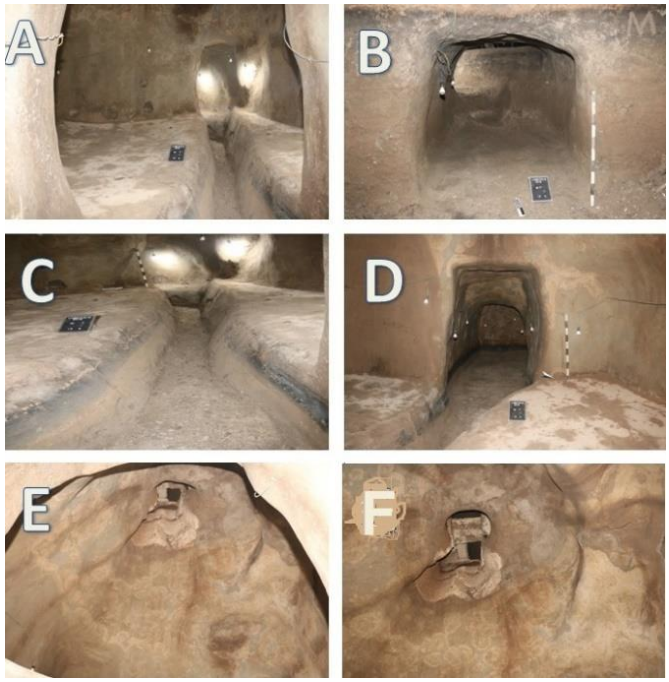


Figure 19: A&B&C&D. the floor of well A showing the channel toward the closed tunnel ending that has a water lead pipe in the bottom of the closing wall. E&F. a view of well A from inside showing the closing lentils of the well mouth.

7. TUNNEL CONSTRUCTION METHOD

1. During the Hellenistic period, Cisterns were the main elements that preserved water for inhabitants. A vertical shaft was first dug into the rock that widened up into the depth. The cistern's shaft was connected with the surface by building a walled neck up to the soil's surface, usually at 15m below the surface level. Cisterns varied in shapes from a funnel or pear to a bottle or cube. Cisterns were coated with two layers of waterproof plaster to hold water. Two methods were employed to collect rainwater in the cisterns: delivering water directly throughout the cistern's mouth or via channels dug into tunnels connecting the cisterns.

2. During the Roman period, a network of tunnels and channels was carved and connected with the main arched tunnels along Main Street's sides to supply all the city's monuments with water. Curving tunnels needed two teams working opposite each other until they reached the determined point.

Floors were leveled and sloped down to allow water to run smoothly, and then walls and floors were covered by two layers of waterproof plaster, coarse and fine.

3. Several pottery shreds were found inside the excavated cisterns, and tunnels that were used to pull up water from these cisterns all were dated to Hellenistic and Roman period (Table 1).

Pottery

Mostly; the excavated pottery from the tunnels were dated to the Late Roman period based on a comparable similar depositions found at the surrounding excavated areas. No coins were found in the tunnel area. All layers yielded a mixture of ceramic from different periods, varied from Late Hellenistic, Late Roman, Late Byzantine and to Early Umayyad.

The following forms of pottery pots are the most dominant forms discovered in the excavation of the tunnels:

Jar

The most common jar type (shape), found in pottery assemblage is a bag-shape jar(Water Jar), with a long and straight neck (short), a ridge between the neck and shoulder, two loop handles on the shoulder, a ribbed body, and rounded –flattered base. The colors are varied from orang (5YR.7/4. 2.5YR.7/4), to reddish (2.4 YR.74).

Bowl

A number of fragment of the bowls were found in tunnel area. The bowls are common in all pottery of excavated area. The bowls are made of well- levegated red (10R.4/5), reddish (2.5YR.5/3), and orang clay (7.5YR), and appeared in a variety of shapes, including carinated, rounded. The rims shapes are variations of thickened with grooves on top, the basis are ring, and flat. Some bowls were imported such as Sigilata ware.

Cooking pot

A large number of cooking pots was found in the fills of excavated area of the tunnel, several example of cooking pot of open and closed shapes.

The opened cooking pot form have carinated shoulder, a horizontal rim, a round base, and two vertical ring handle, extending from the rim to the body. The closed forms have a vertical neck, a flat rim, globular body, and two handles extending from the rim to the shoulder.

Closed form, globular cooking pot, characterized by an everted neck with a round outer rim, a ridge body, and two vertical handles extending from rim to shoulder, the colors are ranging from strong brown, reddish brown (2.5YR.5/4), to red(10R.5/4), and to brownish orang (7.5YR).

Large Jug

A large number of fragment of the jugs were found in tunnel area were in the clay deposits. The jug is common in all ceramic assemblages of excavated area. A globular shape with narrow neck, and round base, one handle extending from rim to shoulder, a ridge body, and the colors are ranging from reddish orang (2.5YR.7/4), to light gray (10YR.8/11), and yellowish orang (7.5YR.8/1).

Juglets

Globular juglets with round base, one handle extending from rim to shoulder. The color is light gray (10YR.8/2).

Basin

Large without handles, with rounded base. The color is orang (5YR.6/3).

Amphora

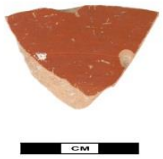
A few fragments of amphora were found, a loop height handle extending from shoulder, to neck. Orang in color (5YR. 5/3).

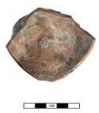
Lamps

Several fragments of lamp were found, undecorated bow-spouted (Herodian) lamp; the color is light gray (10YR.7/1). Fragments of decorated Orang ware (2.5YR.6/4), flat base.

Table 1. Typology of the pottery shreds found inside the excavated cisterns, and tunnels.

Locus / Pail	Material	Classification /Typology	Chronology/ Period	Color / Exterior	Photo	Remarks
L1.P1	Pottery	Cooking Pot	Late Roman	7.5YR.Brawnish Gray		Handle. Broken
L1.P3	Pottery	Deep Bowl	Late Roman	5YR.6/4 Dull Orang		Rim. Broken
L2.P1	Pottery	Jar	Late Roman	5YR.7/4 Dull Orang		Rim, body .Broken
L2.P1	Pottery	Jar	Late Roman	2.5YR.6/4 Dull Orang		Rim. Broken
L3.P6	Pottery	Handle.Jar	Late Byzantine -EarlyUmmayad	2.5YR. 6/4 Dull Orang		Handle. Broken
L3.P1	Pottery	Jar	Late Byzantine -EarlyUmmayad	2.5YR.5/1 Reddish Gray		Bodysherd.Broken
L5.P1	Pottery	Cooking Pot	Late Roman	2.5YR.5/4 Dull ReddishBrown		Handle. Broken

L5.P2	Pottery	Jar	Late Roman	7.5YR.7/4 Dull Orang		Rim, Han-dle.Broken
L7.P1	Pottery	Juglette	Late Roman	10YR.8/2 Light Gray		Base. Broken
L7.P1	Pottery	Bowl. Segel-lata ware	Late Roman	10R.4/5 Reddish Brown		Base. Broken
L7.P1	Pottery	Bowl	Late Roman	10YR.4/6 Red		Bodysherd. Bro-ken
L7.P1	Pottery	Cooking Pot	Late Roman	2.5YR. 5/5 Dull Reddish Brown		Rim. Broken
L7.P1	Pottery	Lamp	Late Roman	2.5YR.6/4 Dull Orang		Base .Broken
L7.P1	Pottery	Bowl.Segellata	Late Roman	2.5YR.5/3 Dull Reddish Brown		Rim.Broken
L7.P1	Pottery	Juglette	Late Roman	5YR.6/4 Dull Orange		Base.Broken

L9.P3	Pottery	Jar	Late Roman	2.5YR.7/4 Pale Reddish Orange		Base. Broken
L9.P3	Pottery	Bowl	Late Roman	10R.5/5 Reddish Brown		Rim. Broken
L9.P3	Pottery	Cooking Pot	Late Roman	10R.6/4 Dull Reddish Orange		Rim.Handle.Broken
L9.P3	Pottery	Bowl	Late Roman	7.5YR.7/3 Dull Orange		Rim. Broken
L9.P3	Pottery	Bowl	Late Roman.SegellataWare	10R.5/2 Grayish Red		Base. Broken
L9.P1	Pottery	Lamp	Late Roman	10R.4/6 Red		Fragment.Broken
L9.P1	Pottery	Lamp	Late Roman	10YR.4/6 Red		Fragment.Broken
L10.P1	Pottery	Jug	Late Roman	2.5YR.7/4 Reddish Orange		Base.Broken
L10.P1	Pottery	Jug	Late Roman	2.5YR.7/4 Reddish Orange		Rim. Broken

L11.P1	Pottery	Bowl. Segel-lata ware	Late Roman	10R.6/5 Reddish Orange		Base Broken
L12.P1	Pottery	Bowl.	Late Hellin-istic-Ear-lyRoman	2.5YR.4/4 Red-dish Brown		
B-C/1	Pottey	Jug	Late Roman	5YR.8/3 Pale Orang		Base Broken
B-C23	Pottery	Cooking Pot	Late Roman	2.5YR.5/3 Dull Reddish Brown		Rim, Handle Broken
B-C/23	Pottery	Basin	Late Roman	5YR.6/3 Dull Orange		Rim. Broken
B-C/39	Pottery	Amphora	Late Roman	2.5YR.5/3 Or-ange		Rim, Handle Broken
B-C/45	Pottery	Jar (water Jar)	Late Roman	10YR.8/11 Light Gray		Rim, Handle .Broken
B-C/38	Pottery	Bowl. Segel-lata Ware	Late Roman	2.5YR.Bright Reddish Brown		Base. Broken

B-C/64	Pottery	Jug	Late Roman	7.5YR.8/1 Light Yellowish Orange		Base. Broken
B-C/64	Pottery	Jug	Late Roman	5YR.8/1 Light Gray		Base.Broken
B-C/100	Pottery	Bowl	Late Roman	10R.4/5 Reddish Brown		Rim.Broken
B-C/97	Pottery	Bowl	Hellinistic	2.5YR.2/1 Red-dish Brown		Base. Broken
C-B	Pottery	Lamp	Late Roman	10YR.7/1 Light Gray		

7. CONCLUSION

One of the most prominent characteristics of Umm Qais (Gadara) is the water supply system that produced a fine example of human ingenuity and skill to react with the available natural resources. The water supply system and its associated installations, such as cisterns, tunnels, channels, pools, ceramic, and lead pipes, collected and stored water from rainwater and the springs surrounding the site or far away from it. However, further research of this system is needed.

It is a rare type of water supply system since it is the first to find in Jordan that belong to the Hellenistic and the Roman periods in this well-preserved condition. The system's elements, deep cisterns of bottle shape dated to Hellenistic period, cut into the rock 13m deep, coated with plaster are unique. Almost 7m of settled strata above these cisterns were excavated down to the Hellenistic temple's foundation revealed several phases of settlement in this area of the site.

During the Roman period, due to the steady increase of population, the site expanded. Therefore, a massive demand for securing water for the inhabitants eventuated. Several water installations: tunnels, pools, and cisterns, were constructed to overcome this problem using Hellenistic period technology. The uncovered tunnels characterized by shafted entrances for preserving and controlling water distribution all indicate a well-organized water supply system.

This discovery is unique in Jordan and the surrounding area. Further investigation is a must to deepen the understanding of the water supply system at umm Qais.

ACKNOWLEDGEMENTS

This work was fully supported by the Deanship of the Scientific Research at Yarmouk University, Jordan.

REFERENCES

Ali. A. (2014) Olive oil production in a semi- arid area: evidence from roman tell es-sukhnah, *Mediterranean Archaeology and Archaeometry,* Vol. 14, no 2, pp. 337-348.

Beaumout, P. (1985) Man-inclused Erosion in northern Jordan. *SHAJ* II, pp. 291-297.

Browning, I. (1982) *Jerash and the Decapolis*. Printed by Butler and Tanner LTD, London.

De Vries, B. (1973) The North Mausoleum at Umm Qeis. *ADAJ,* XVIII, p. 77.

Flon, C H, et al., (1988) The world Atlas of Architecture, Transl. to English by Christopher Dufton, et al.
Forbes, R. J. (1955) *Studies in the ancient technology*. Vol I, Leiden.
Glueck, N. (1951) *Exploration in Eastern Palestine, IV*, Part 1, The Annual of the American Schools of Oriental Research, Vol, XXV_XXVIII, pp. 115-144.
Guinee, R, and Mulder, N. (1922) Survey of the Terrace and Western Theater Area in Umm Qais. *ARAM*, 4, 1-2, pp. 387-406.
Guinee, R.; Mulder, N.; Vriezen, K. (1996) The Façade of the Voulted Rooms A long the So-called Cardo in Umm Qais (Ancient Gadara) Area III. *ADAJ,* XL, pp. 207-215.
Helmes, S. M (1981) *Jawa Lost City of The Black Desert*, Methuen.
Hoffman, A. (1997) Gadara-Umm Qais. *AJA* 101, pp. 513-514.
Holm- Nielsen. S.; Nielsen, I.; and Gorn Anderson, F. (1986) The Excavation of Byzantine Bathes in Umm Qais. *ADAJ* XXX, pp. 219-322.
Holm- Nielsen. S.; Nielsen, I.; and Gorn Anderson, F (1993) Gadara- Umm Qais III. Die Byzantinishen Therma 17.
Kerner, S. (1992) Umm Qais-Gadara Recent Excavation, *ARAM*, vol, 4, 1-2, pp. 407-423.
Kerner, S. (1994) The German Protestant Institute for Archaeology and Other German Projects in Jordan, *NEA*, Vol. IV, pp. 49-64.
Kerner, S. (1997) Umm Qais-Gadara: A preliminary Report 1993-1995. *ADAJ* XLI, pp.283-299.
Kerner, S. (1997c) Water Management in Northern Jordan: The Example of Gadara- Umm Qais. *SHAJ* VI, pp. 265-270.
Kerner, S. and Hoffman, A. (199) Gadara- Umm Qais: Preliminary Report on the 1991 and 1992 Seasons. *ADAJ* XXVLL, pp. 359-384.
Landels, J. (1988) Civilization of the ancient Mediterranean Greece and Rome. *Engineering* (edited by Grant and Kitzinger, R), New York, Vol, I, pp. 328-352.
Lange, M. (1968) *Water works in the Athenian Agora*, American School of Classical Studies at Athens, New Jersey.
Mittman, S. (1970) Beritage zup Siedlungs and Territorial Geschichute des Nordlichen Ost Jordan lands. Otto Harrossowitz, Wiesbaden.
Nash, E, (1981) *Pictorial Dictonary ancient Rome*, Vol.1, New York.
Obeidat, B and Miqdady, H. (2021) Preserving the Traditional Watermills I Wadi Orjan Using an analytical Hierarchy Process, *SCIENTIFIC CULTURE,* Vol. 7, No. 1, (2021), pp. 21-30. DOI:10.5281/zenodo.4107177.
Peake, F. (1958) *History and Tribes of Jordan.* University of Miami Press, Florida.
Plomer, H. (1973) *Vitruvius and later Roman Building Manuals*, Cambridge University Press.
Schumacher, G. (1890) *Northern Ajlun Within the Decapolis*. London.
Seetzen, U. (1859) Reisen Durch Syrien Palestine die Trans Jordan laner, Arabia Petra und unter Aegypten, Berlin.
Shiyab, A. (2015) A Preliminary Report about Archeological Excavations at Umm Qays "Gadara" 2014 Newsletters, (Faculty of Archeology and anthropology, Irbid, Yarmouk University) 35, pp. 3-7.
Shiyab, A and Al-Shorman, A, (2015) Excavations at the archaeological Site of Um Qeis (GADARA), north Jordan (Seasons 2013, 2014), *Journal of Faculty of Archeology*, Vol.18, Cairo University.
Shiyab, A (2016) Archeological Excavations at Umm Qays "Gadara" 2015, Newsletters, 36, pp. 9-13, Faculty of Archeology and anthropology, Irbid, Yarmouk University.
Shiyab, A and Others (2017a) Discovery of Hellenistic temple at Umm Qeis site "Gadara", in Northern Jordan, First result, by, *Mediterranean Archaeology and Archaeometry*, Vol.17, No2, pp.137-148.
Shiyab, A., (2017b) Reconstruction of Hellenistic Temple discovered at archaeological site of Umm Qais (Gadara), North Jordan (architectural and archaeological study). *Journal of Faculty of Archeology*. Cairo University, volume 20, pp. 1-30.
Shiyab, A. et al., (2019) Investigation of late Roman pottery from Gadara of the Decapolis, Jordan using multi-methodic approach, *Journal of Archaeological Science*: *Reports*, Vol. 2, pp. 100-115.
Shqiarat. M. (2019) History and Archaeology of water management in Jordan Through Ages, *SCIENTIFIC CULTURE, Vol. 5, No. 3, (2019), pp. 41-54. DOI:10.5281/zenodo.3340109*
Vitruvius, (1914) The Ten Books on Architecture. Translated by Z. Morris Hicky Morgan. Dover Publication, Inc, New York.
Wagner-Lux, U and Vriezen, K. (1982) Vorlaufiger Berichet uber Die Aus grabungen in Gadara-Umm Qais in Jordanian in Jahre 1980, *ZDPV* Band 98, pp. 153-162.

Wagner-Lux, U. and Vriezen, K (1984) Preliminery report of the excavations in Gadara (Umm Qeis) in Jordan, 1980. *ADAJ,* XXVIII, pp. 87 – 90.

Water Authority (1980) Rain full in Jordan for the water year 1976-1980, Technical Paper No 50, Amman.

Weber, T. (1988) Gadara of the DECAPOLIS: A summary of the 1988 season at Umm Qais. *ADAJ* XXXII, pp. 349-352.

Holm- Nielsen. S.; Nielsen, I.; and Gorn Anderson, F. (1993) Gadara- Umm Qais III. Die Byzantinishen Therma 17.

Weber, T. (1989) Gadara: An urban centre in the Decapolis. Some preliminery remarks on the development. Forth international conference on the history and archaeology of Jordan, Lyon, May 1989, *SEPA* 61, pp. 1- 20.

Weber, T. (1990) *Umm Qais Gadara of the Decapolis*. Al Kutba publishers, Amman.

Weber, T. (1990a) One hundred years of Jordanian, German fieldwork at (Umm Qais) 1980 – 1990. *Near East in Antiquity* I, pp. 123 – 141.

Weber, T. (1991b) Gadara of the DECAPOLIS: Tiberrade Gate Qanawat el Far,oun and Bait Rusan Achievment in Excavation and Restoration at Umm Qais 1989-1990 *, NEA* VII, pp 123-133.

Weber, T. and Khouri, R. (1989) Umm Qais – Gadara of the Decapolis: A brief guide to the antiquities, Amman.