Management of water resources over time in semiarid regions: The case of Gerasa/Jerash in Jordan

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Abstract
This article tackles ways in which archeological research can give perspectives on the development of water management and the strategies behind such management systems in ancient societies of historical periods. It focuses on the city Gerasa/Jerash in northern Jordan, which was one of the middle-sized Decapolis cities that flourished from the Roman period (first century CE) until the end of the Umayyad period, when a devastating earthquake hit the city in 749 CE bringing urban life to an almost complete halt. Only in the middle Islamic period (13th century CE) the site was resettled. The article focuses on how scattered archeological evidence—which is usually not published by archeological projects due to its feeble nature—can bring new knowledge to light about the ways in which water was managed in urban contexts, in particular in semiarid regions, such as the region in which Gerasa was located. Pushing borders for how we can frame and interpret archeological evidence in wider diachronic perspectives is a necessity in archeology—not least in regions where archeology is under threat due to modern urban development and the general lack of resources to develop cultural heritage management plans.

KEYWORDS
near East, resilience, sustainability, urban landscapes, water management

1 | INTRODUCTION

In urban contexts, water management is alpha and omega for life to be sustainable. Cities are rarely self-sufficient and need resources brought to their inhabitants in various ways.1 Fresh water is one of these resources and one which is entirely basic for urban life to exist and survive. Therefore, water is heavily managed within urban contexts in order to be made readily available under controllable circumstances allowing for the right amounts of water to be accessible to people at the right points in time. In recent years, we have been confronted with numerous examples where, for example, changing weather conditions have created catastrophic scenarios when either too much or too little water has been available to the population.2 Such situations, including flooding and droughts, would have been just as dangerous for ancient societies, since water management installations and the maintenance of such installations were fragile matters in premodern societies, as such installations were
not usually constructed to withstand large and unexpected fluctuations in water amounts, and also might not have been constructed to withstand long-term developments and changes in water flows.

While developments and changes in water management strategies as well as reasons for such changes must be studied in a diachronic perspective, archeological research focusing on the historical periods in the Middle East and specifically working within urban contexts do not usually take diachronic approaches to the development of water management systems and use of water resources. We advocate that there is a need for a shift toward longue durée studies, if we are to fully gauge the ways in which these societies sustained themselves and dealt with threats to their water resources, which either could have been immediate or have developed over time, as well as to truly understand the knowledge these societies had into the complexities of water resources and the management systems, which were needed in order to remain resilient as urban societies over long periods. Such a shift in approach calls for stepping outside one's archeological comfort zone, which too often is limited by an artificially imposed chronological range through the way archeology has developed as separate disciplines (periodization); on the one hand studied through the lens of geographic regions, and on the other hand through chronologically limited periods. We here argue that such steps are necessary in order to unleash the potential in archeological research for understanding the knowledge that past societies had.

While archeological projects in the Middle East dealing with historical periods most often focus on fairly narrow time spans or single monuments or buildings, new trends in archeology have begun to make their way into the region, opening perspectives on the way in which diachronic explorations bring new knowledge to light about the ways in which urban societies in the historical periods developed over millennia. In such a perspective the management of water resources must stand as a central aspect to enquire into, since the Middle East is a region in which the management of water has been crucial for millennia and archeological evidence pertaining to several millennia therefore is available to us.

As our point of departure, we take the archeological fieldwork undertaken by the Danish-German Jerash Northwest Quarter Project from 2011 to 2016 in Roman to early Islamic Gerasa/Jerash. The article intends to lay open the ways in which water management development and the impact of water management on urban landscapes can be explored in a diachronic perspective in a region, which was heavily dependent on efficient management of its water resources for urban life to remain resilient. The focus is on the city's water supply for the city and a contextualization of it within the broader urban cultural history. Hinterland irrigation and agricultural water management are not central to this paper due to lack of research undertaken. However, it can be assumed that concurrent developments will be observed there. The reflections and conclusions are intended to give impetus to further research of this kind as well as to push the borders for comparative research in order to draw parallels to modern-period societies in regions such as the one in which Gerasa is located.

2 FROM GERASA TO JERASH: A CITY WITH A HISTORY OF MORE THAN TWO MILLENNIA

The ancient urban site of Gerasa/Jerash in modern northern Jordan has been the focus of archeological research since the early 20th century, when exploratory archeological work was done by a German mission, which at this time was mainly working at Baalbek and during a summer break went to Gerasa (Kraeling, 1938a, p. 3; Lichtenberger & Raja, Forthcoming) (Figure 1). They, among other things, explored around the city’s Nymphaeum, a monumental water installation on the main street of the city located next to the entrance to the Sanctuary of Artemis. They never published their exploratory work and it was only during the work of the Anglo-American mission headed by C. H. Kraeling that studies on the water management of Gerasa in the Roman period were published. Since then several teams have excavated at the site and some have focused on different aspects of water usage in the city and the management of it throughout the periods in which the city flourished, but usually with a focus on specific aspects such as the bath complexes or the water pipes on the main street. Only recently, has it been attempted to explore the use of water and water management within and outside the city in a longue durée perspective in order to understand the complexities involved and the knowledge circulating in Gerasene society over several hundreds of years.

Gerasa was located on the river Chrysorrhoas, the Gold River (Figure 2). The city even incorporated the name of the river into its official name and called itself Antiocheia-on-the-Chrysorrhoas-formerly-Gerasa, which is seen on some of the city’s coins. Gerasa was a middle-sized city covering approximately 90 ha that were circumferenced by city walls constructed in the second century CE (Figure 3). The city was located in the region called the Decapolis, the 10 cities. This denomination in fact covered an extensive region and included more than 10 cities. Gerasa was situated in a semi-arid region, but the territory of Gerasa was fertile for large parts of the year in particular due to the many natural springs and not least the river, which were also exploited for agricultural purposes. The river, which literally cut the city into two halves, an eastern and a western part, was situated in a deep gorge in the stretch that ran through Gerasa (Lichtenberger, Raja, Seland, Kinnaird, & Simpson, 2019, p. 6) (Figure 4). Therefore, the two halves of the city were only connected by bridges, most likely five, constructed in
FIGURE 1  Map of the Decapolis region. © Danish-German Jerash Northwest Quarter Project

FIGURE 2  Map of the hinterland of Gerasa. © Danish-German Jerash Northwest Quarter Project. Map data: Google, Data SIO, NOAA, U.S. Navy, NGA, GEBCO Landsat/Copernicus
FIGURE 3 Map of Gerasa/Jerash. © Danish-German Jerash Northwest Quarter Project

FIGURE 4 Profile of the city and the steep wadi. (Copyright expired. Therefore, printed after Schumacher, 1902, Taf. 7)
The city's infrastructure was closely tied to the course of the river—much closer than many other cities located by, but not usually on both sides of, rivers in the ancient world.

The city flourished from the early first millennium CE until an earthquake hit the region in 749 CE (Lichtenberger & Raja, 2019a). In these almost eight hundred years, the city underwent a continuous development with massive monumental buildings being constructed in the first three centuries CE, including extensive water pipe systems for running water, large bath complexes, and a Nymphaeum, as well as a several cisterns— intra- and suburban—to serve the water needs of the city's inhabitants, including and not least those to do with hygienic purposes. All these water installations were surrounded by other projects, which served the purpose of securing flowing and collected water for the installations, such as sub- and extra-urban rock-cut canals as well as cisterns. In later periods, water management systems were upkept and only seem to have changed to a different management system in the Byzantine to early Islamic periods, where private houses have been found, which held their own water installations, that is, in-house rock-cut bottle-shaped cisterns with water-catching systems on the roofs connected to them. The large bath buildings of the Roman period were no longer in use in the Islamic period, which is one further indication of the change in the water management system, potentially due to less running water being available.

3 | INVESTIGATING WATER MANAGEMENT ON THE BASIS OF SMALL-SCALE EXCAVATIONS

Water management has been a theme of research in the Decapolis region since decades. This in parts semiarid region was very dependent on water being managed thoroughly in order to upkeep both agricultural activities and urban infrastructures. However, no entire city's water infrastructure has been researched in depth until now and neither can Gerasa's water management...
be studied in details for all periods or even all parts of the city and its extensive hinterland. Important work has been done on Gadara’s (Umm Qais) water infrastructure as well as its hinterland, showing that water indeed was managed to much more extensive degree than often supposed (Keilholz, 2017). Furthermore most other Decapolis cities hold monuments that testify to water having been managed extensively (Döring, 2016). However, in most cases preservation of extensive amounts of water infrastructure is not available to us, and Gerasa therefore constitutes an important case study site through which to study water management over time from classical antiquity into the early Islamic period.

Since 2011 the Danish-German Jerash Northwest Quarter Project has conducted archeological research in Gerasa/Jerash in the so-called Northwest Quarter of the city, which is located on the highest point within the walled city. The area, which covers approximately 4 ha, was densely covered with built structures as a geophysical survey undertaken in 2011 showed and following excavation campaigns confirmed (Kalaitzoglou, Kniess, Lichtenberger, Pilz, & Raja, 2012; Lichtenberger & Raja, 2019b) (Figure 5).

Although the Northwest Quarter was located on the periphery of the Roman and late antique city, its urban development clearly reflects and is representative of general urban processes. Especially the water supply installations shed light on broader issues of urban development, starting with the centralizing impact of the Roman Empire in the early second century CE and the subsequent long-term prosperity. From the sixth century CE onwards far-reaching changes in the water management systems are observed, which by the end of the early Islamic period had resulted in firm responses through decentralized water storage strategies in the domestic settings. Being the highest point within the walled city the Northwest Quarter must also have been vulnerable to change and disruptions to a higher degree than some other lower lying parts of the city, which might have been able to draw on a string of other water resources. In this way the Northwest Quarter makes a good case study area and a bench mark for slow changes as well as sudden impacts, which overall might have affected the entire city, but cannot be traced in the archeological record as easily as in the Northwest Quarter.

It should be noted that the Northwest Quarter and its surroundings remain fairly well documented through the work undertaken by the Danish-German Jerash Northwest Quarter Project as well as the survey work of Don Boyer (Boyer, 2016a, 2016b) in comparison to other parts of the city, in particular the eastern part. However, overall the general developments

**FIGURE 6** The limestone mountainside from which the spring in Suf originates, image from 2015. © Danish-German Jerash Northwest Quarter Project
FIGURE 7  Altar Block close to a spring in Suf. © Danish-German Jerash Northwest Quarter Project

FIGURE 8  The partly restored Nymphaeum on the main street in Gerasa. © Danish-German Jerash Northwest Quarter Project
correspond to those in other parts of the city as far as we can tell from the known archeological evidence. The fact that the eastern side of the wadi was resettled in the 19th century may be one indication that water in fact was more readily available—at least at this point in time—than in the Northwest Quarter (Boyer, 2016b, p. 522). But it also needs to be underlined that agricultural activities seem to have taken place in the area of the Northwest Quarter in the 19th century, certainly indicating that water must somehow have been brought to this area in this period as well. Since archeological evidence is not available to any great extent from the eastern part of the city, it remains impossible to firmly conclude that this side of the wadi also was affected by the slow climatic changes and the decline in the management of the hinterland. However, until now nothing speaks against such a conclusion and as shown, the resettlement in the 19th century went hand in hand with the development of agricultural activities on the western side of the wadi as well, indicating that at least at this point in time water was available again in both locations.

Out of a total of 24 trenches excavated in the Northwest Quarter between 2012 and 2016, 13 trenches yielded evidence for various sorts of water management in the city, spanning a period of more than 700 hundred years (Lichtenberger & Raja, 2016a, 2016b). This underlines that water management was a continuing issue in the Northwest Quarter, but it also shows the
central importance that water management held in this area and which might be representative of its role within the city in general. The evidence for water management in the Northwest Quarter includes installations for running water (water pipe systems), collected water (cisterns), as well as waste water (sewages). The main parts of the evidence stem from the Roman and late Roman periods (trenches A, S, E, H, F, L, O, X, Q, M) and the early Islamic period (trenches C, K, and P), while evidence relating to installations constructed in the Byzantine period remains scarce. We here attempt to disentangle the various phases of the installations and their usage in order to understand the changes in water availability over time as reflected in the water management installations in the Northwest Quarter and discuss how these developments reflect overall changes and their backgrounds.

3.1 | The impact of the Roman framework

When Trajan established the province Arabia in 106 CE, Bostra in southern Syria was made the capital, but Gerasa became the place where the financial procurator of the new province resided (Kraeling, 1938a, pp. 46–49). This new position of the city within its regional context triggered public building activities, and most of the Roman-period monuments belong to the period after 106 CE. The city experienced another urban boost under the emperor Hadrian, who spent the winter of 129/130 CE in Gerasa with his troops. It was in the second century CE most of the Roman-period building projects were
initiated. The activities in the Northwest Quarter related to quarrying, providing construction materials for the building projects as well as to the construction of extensive water management structures.\textsuperscript{24}

In Roman-period Gerasa, there was a heavy investment in public resources for water management, an investment which reached far beyond the city’s walls. There is ample evidence for rock-cut canals in the area west and northwest of the city, which would have belonged to an extensive water management system that would have served the entire upper part of the city (the western side) with water.\textsuperscript{25} Furthermore, there are remains of Roman-period installations in the area of the village Suf, where the river had its source (Figure 6).\textsuperscript{26} These remains might have belonged to cultic activity connected to the spring (Figure 7).

Since the western side of Gerasa was too high up in relation to the river, this part of the city, covering approximately half of the city’s entire walled area, was fed by water coming from the springs to the west and northwest of the city. All this water had to be brought into the city by means of artificial water management systems such as canals and cistern systems.\textsuperscript{27} Such complex water management systems would have required maintenance on a continuous basis. Due to its location, the Northwest Quarter presents an ideal case area for studying complex water management system processes. Furthermore, the monumental public buildings, such as the second century CE Nymphaeum (Figure 8), two large sets of urban baths (the so-called West Baths and the so-called East Baths) (Figures 9 and 10), the suburban baths at Birketein, the massive cistern in the Northwest Quarter, the water gates controlling the flow of the river through the city, and the structures built around the natural springs, all show that immense effort was invested into controlling and optimizing water resources in the first three centuries CE in the city (Lichtenberger & Raja, 2016a for references to these monuments).

In 2013 as well as in 2016, parts of a cistern located on the very top of the hill were explored in trenches A\textsuperscript{28} and S (Figure 11).\textsuperscript{29} This cistern deserves special attention. The cistern was a large east–west-oriented rock-cut structure. It had been a subterranean part of a monumental building that at one point in time in the third or fourth century CE had been destroyed and razed to the ground. All inventory that had not been removed from the building as well as architectural elements had been filled into the cistern, before it was closed off with several fill layers, debris as well as homogenous layers of fist-sized stones. Cooking pot deposits had been set in some of the layers during the infilling, underlining the intentional nature of the filling up and closing off of the cistern (Figure 12) (Lichtenberger & Raja, 2015).

The tripartite cistern had high-quality pilaster columns along its long sides, which had carried the vaults. In the west end of the cistern, a staircase led down into the cistern. The staircase was decorated with elaborate wall paintings that had been renewed in several phases as the multiple layers of paintings found indicate. The staircase led down into the cistern well beyond the optimum filling level. Both the decorated staircase as well as the fact that it went below the optimum filling level of the
cistern indicate that the cistern did not purely serve as an ordinary water reservoir but also must have had a representative function. No exact parallels to this structure have been found, but several sanctuaries in antiquity were connected with water cults and therefore held cisterns, lakes (sometimes artificial) or pools.30 The decoration of the paintings point to an early Roman date for the earliest paintings and the closest parallels are found in Herodian-period wall paintings found in the palaces of Herod the Great.31 The date of the infilling of the cistern seems to have been the third or fourth century CE also judging from coin finds, radiocarbon dates as well as the style of the stucco and wall painting decoration, which came from the building on top of the cistern.32 The embellishment of the staircase leading to the cistern, the overall high quality of the cistern and the nature of the finds found in the fills in the cistern, which had come from the building standing on top of the cistern, indicate that we have to do with a particular building. The cistern was located at the utmost highest point within the walled city with access to water that was brought in from the west directly to the lavishly decorated cistern located beneath a monumental building of the early Roman period of importance, judging from the finds and the size as well as location of the building.

One suggestion is that the monumental building that was razed to the ground and the cistern below it were part of the pre-Hadrianic Artemision, which for one reason or the other was closed off intentionally, and thereafter the area was never touched again in the Roman period. Whether the closing off of the complex potentially had anything to do with changes in the water accessibility in the area remains to be seen, but it might have been one factor in the falling out of use of the complex, and the intentional closing by the cooking pot deposits underlines the ritual nature of the closing of the complex. An inscription stemming from the first century CE that mentions a sacred lake of Artemis situated in a portico supports such an interpretation.33

From an entirely functional point of view, the most important water management structure in the Northwest Quarter was a large water reservoir on the south slope of the Northwest Quarter. Radiocarbon dating of the mortar lining this water reservoir, the largest cistern within the city, a rock-cut structure measuring ~40 by 18 m, showed that the cistern most likely was

**FIGURE 13** Plan of the cistern on the south slope in the Northwest Quarter © Danish-German Jerash Northwest Quarter Project
constructed in the early second century CE (Lichtenberger, Lindroos, Raja, & Heinemeier, 2015) (Figure 13). This structure is an important evidence for Roman-period monumental installations for water management. Furthermore, the excavation campaigns undertaken in the period 2012–2016 brought further water management installations to light. In the campaigns of 2013, 2014, 2015, and 2016 areas in and around the large rock-cut cistern were investigated, bringing forth information about the usage phases of the cistern as well as the layout (trenches F, L, O, and X).

In 2013, in situ water pipes and their beds were excavated in trenches E and H (Figure 14). In 2014, water canals were excavated in trenches K and M. Also in 2015, a sewage canal was excavated in trench Q.

The absolute main part of the evidence connected with water management installations in the Northwest Quarter stems to the period in which the city was under Roman rule, a time when we also know from the rest of the archeological evidence from the city and from the written sources that large investments were made in order to embellish the city's center with numerous monuments and to make it functional and representative within an imperial framework. This development seems to have taken place from the Trajanic period onwards and have continued into the Hadrianic period, so the later first and first half of the second century CE seems to have been the period in which the most extensive developments of the city's water infrastructure took place. After that, maintenance and developments, such as the changes made to the cistern on the south slope, seem to have been caused due to profound changes in the water supply.

3.2 | The late Roman and Byzantine periods: A period of slow (and invisible) decline?

The prosperous urban development of the Roman period continued into the Byzantine and early Islamic periods (Lichtenberger & Raja, 2019). Many churches were erected in the city during the Byzantine period (Fisher, 1938b; Michel, 2011; Raja, 2015), and urban encroachment observed throughout the excavated parts of the city indicates a peak of population, which continued up to the mid-eighth century CE (Lichtenberger & Raja, 2019a). However, during the sixth century CE symptoms of crisis that also affected the water management systems are detected (Lichtenberger et al., 2019, pp. 10–11). Furthermore the Justinian plague also reached Gerasa, which is visible in, for example, the burials found in the Hippodrome (Kehrberg & Ostrasz, 2017; Meier, 2016). During this period, the sixth century CE, changes in the agricultural strategies are also detectable (Lichtenberger et al., 2019, pp. 6–8, pp. 13–14). Through new research undertaken in the hinterland of the city, it is now clear that during the sixth century CE, a decline in the maintenance of the agricultural terraces took place (Lichtenberger et al., 2019, pp. 13–14). This decline was most likely related to changing climatic conditions, which took place...
only slowly, during the so-called “late antique little Ice Age” (Büntgen et al., 2016). This deep-reaching, slow climate change can also be observed in the ways in which water was managed in the Northwest Quarter (Lichtenberger et al., 2019, p. 14).

While the late Roman and Byzantine-period city relied heavily on the Roman-period water infrastructure that was in place and had been developed since the early Roman period, some changes in water resource management within the city are clearly detectable. The largest cistern within the walled city, located on the south slope in the Northwest Quarter, was converted into a production area, and a natural cave under it transformed into a smaller cistern (Lichtenberger et al., 2015). Both situations indicate that the water pipe system had come to a halt in the Northwest Quarter at this point in time (Lichtenberger et al., 2015, pp. 121–122, p. 125). So while the urban landscape in many ways was prospering in the late Roman and Byzantine periods, it is through the water management systems possible to detect that water was not as available and easily manageable as earlier. Climate change was potentially one factor on the way in which agriculture as well as urban water infrastructure was managed.

3.3 Byzantine and early Islamic domestic responses to changes in water supply

The Northwest Quarter has displayed early Islamic evidence dating to the time of the earthquake in 749 CE (Lichtenberger & Raja, 2016b, 2017, 2019a). A set of domestic houses that collapsed when the earthquake hit Gerasa on 18th January 749 CE

**FIGURE 15** Plan drawing of trench C with the closed-off, bottle-shaped cistern. © Danish-German Jerash Northwest Quarter Project
have been excavated on the East Terrace in the Northwest Quarter and give insight into the management of water resources in the middle of the eight century CE and lead to the conclusion that water management seems to have been a matter which had to be dealt with by the private households.

The evidence for water management in the early Islamic period pertains exclusively to evidence from domestic contexts. In 2012, a bottle-shaped cistern was excavated in trench C38 (Figure 15) and in 2015, a bottle-shaped rock-cut cistern in a house was excavated in trench P (Figure 16). The cistern in trench P as well as the water catchment installations surrounding it shows that water was collected locally and came from installations on roofs collecting rain water. No running water seems to have been available in these houses. This was also the case in the early Islamic houses excavated in the 1980s on one of the side streets branching off the city's main street (Gawlikowski, 1986). In the early Islamic period, a small Roman bath complex, which had already fallen out of use, was converted into a mosque and no installations for running water have been published as belonging to this complex either (Barnes et al., 2006; Blanke, Damgaard, Simpson & Walmsley, 2007; Rattenborg & Blanke, 2017).

The decline of the centralized supply of running water for Gerasa during the late Roman and Byzantine periods meant that the inhabitants of Gerasa had to cover their water needs through different means. Since the public authorities did not provide a centralized water supply, decentralized and individual solutions had to be developed, and this is the context in which cisterns
were implemented into domestic buildings. After the earthquake of 749 CE, there is no evidence for attempts to reinstall water management systems in this part of the city and until now we do not even grasp the ways in which the middle Islamic settlement was supplied with water when it came to the private settlement. In the Islamic period, further changes seem to have taken place and houses display a more private focus in the ways in which water resources were managed. It should be mentioned that we until now do not have any evidence for water management installations dating to the middle Islamic period, although the middle Islamic settlement on the top of the hill seems to have been of a noticeable size (Lichtenberger & Raja, 2018b).

4 | CONCLUSION

While focus here has been on presenting and contextualizing evidence from one relatively small area in Gerasa/Jerash, such an approach also shows that through one theme—water management in a diachronic perspective—it is possible to investigate in which ways such management developed and how vulnerable such systems were and to show that the reasons for seemingly sudden or slow developments can indeed be disentangled when investigated in a diachronic perspective and held up against other developments, such as shift in political and economic systems, climate change or water availability in general including technology management.

It is clear that extensive attention was given to implement urban water infrastructure systems in the Roman period and that these systems were maintained until the effects of a slow climate change made it a necessity to undertake massive shifts in the way in which water resources were managed in the Byzantine period. While an entirely successful adjustment seems to have taken place and have been implemented by the early Islamic period, the earthquake of 749 CE seems to have devastated Gerasa/Jerash so profoundly that the city did not manage to secure resources in order to reconstruct the city entirely. Furthermore, it remains to be investigated in which ways the middle Islamic settlement sustained itself with water, when the site was reoccupied more extensively again in the Medieval period, since archeological research until now has not yielded evidence for water management in this period.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

AUTHOR CONTRIBUTIONS

Achim Lichtenberger: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; software; supervision; validation; visualization; writing—original draft, review, and editing.

Rubina Raja: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; project administration; resources; software; supervision; validation; visualization; writing—original draft, review, and editing.

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ENDNOTES

1 Several theoretical works have been concerned with the city as a consumer of goods brought to it and a driver of economies. The most influential theoretician to this day, which over and again is quoted despite the bundle-criteria concept that his work is focused around, remains in sociology Max Weber, Die Stadt Weber, 1921, which has also deeply influenced archeology—often also too uncritical. It is not the aim of this article, however, to recapitulate discussions on definitions of urbanism (Raja (2016), pp. 76–78 or Raja and Sindbæk (2018) for further references to the broad range of discussions and definitions). Weber, 1921 (ed. Karsten Worm 1999). Furthermore, Childe (1950) has also had an immense impact on the way in which the study of urban societies has been framed within archeology. While both works were impactful for their time and decades thereafter, they today often also present us with constraints, since they in several ways are outdated, but still used as points of departure in new theoretical work. Newer useful perspectives on urban societies and their complexities include: Renfrew (2008); Taylor (2012).

2 For example, flash floods in various places in Europe and the drought in Cape Town in 2018.

3 However, some attempts have been made to investigate such systems over time. See for example: Scigne (2004) and Döring (2016). Nonetheless, studies such as these consist either of several contributions that deal with restricted periods or do not consider the longue durée in its own right.
In Gerasa, there is also evidence for cults, apart from that of Artemis, which were connected with water rites. These include the Maiumas festival.

See Stott et al. (2018) for a study which integrates modern data with older plans and aerial photographs in order to move forward the understanding of changing landscapes and aspects of water management as well. See in particular pages 4–7 for discussion of water management structures.

Much of this research has been summed up in Lichtenberger and Raja (2016a).

See Lichtenberger and Raja (2016a) for an overview of the largest cistern in the Northwest Quarter. Also see Lichtenberger, Lindroos, Raja, and Heinemeier (2015) for the large cistern on the south slope in the Northwest Quarter. Also see Kraeling (1938a) as referenced above in note 9.

For these coins, see Welles (1938), No. 30, 56/57, 58, 69, 143–145, 147, 153, 192, 251; Spijkerman (1978), pp. 160–163; Lichtenberger (2003), pp. 197–198. See Bürckner (1899), vol. 2, pp. 519–520 for the 12 other cities sharing the epithet “of the Golden river.”

See Raja (2012), pp. 137–189 for an overview of the city's development.

Pliny *Naturalis Historia* V, 18, 74 mentions 10 cities and Claudios Ptolemaios (5.15.22–23) lists 18 cities as belonging to the Decapolis. See Lichtenberger (2003), pp. 6–20 for the term “Decapolis.” Also see the recent review of Dan and Nodet (2017) by Sartre (2018) on the term “Coele-Syria and the Decapolis.”

See Lichtenberger and Raja (2016a), pp. 99–101. See Schumacher (1902), p. 124 for the mention of four, possibly five bridges spanning the ancient river within the walled city. See Fisher (1938a), p. 14 for the so-called South Bridge spanning the river in a prolongation of the layout of the Sanctuary of Artemis. See Brizzi, Sepio, and Baldoni (2010), p. 347 for the newest research on the South Bridge. Also see Brizzi (2018) for a recent contribution on the status of research by the Italian Mission on the Sanctuary of Artemis, which includes the monumental propylaea system that also integrated the South Bridge.

An overview of references to water installations in and around Gerasa can be found in Lichtenberger and Raja (2016a). For some of the monuments see the following references: Bath complexes see: Lepaon (2008); Seigne (2002); Seigne (2004); Seigne (2007); and Seigne (2008). Furthermore, see Lichtenberger, Lindroos, Raja, and Heinemeier (2015) for the large cistern on the south slope in the Northwest Quarter. Also see Kraeling (1938a) as referenced above in note 9.

Lichtenberger and Raja (2016a), in particular pages 101–106.

Trench C: Kalaitzoglou, Lichtenberger, and Raja (2013) Kalaitzoglou, Lichtenberger, & Raja, 2015, pp. 68–75; Lichtenberger, Raja, and Sørensen (2013) Lichtenberger, Raja, & Sørensen, 2015, p. 13. Trench K: Kalaitzoglou et al. (2015/2018), pp. 48–49.

See the recent publication by Lepaon, Turshan, and Weber-Karyotakis (2018) on the new excavations in the East Baths.

See note 7 for references to the project.

See Lichtenberger and Raja (2018a). See also Lichtenberger and Raja (2017a) for general considerations relating to the Northwest Quarter.

See the relevant preliminary reports referred to in the following sections.

See Lichtenberger et al. (2015) for an overview of the largest cistern in the Northwest Quarter.

Lichtenberger and Raja (2016a), in particular pp. 105–106.

Nothing has been published on these installations, but cuts in the rocks close to the mouth of the spring are visible. Also see Lichtenberger and Raja (2016a), pp. 102–104. See Steuernagel (1926), pp. 260–261 and Mittmann (1970), p. 95 for the Roman-period ruins in Suf detected in earlier surveys.

See Stott et al. (2018) for a study which integrates modern data with older plans and aerial photographs in order to move forward the understanding of changing landscapes and aspects of water management as well. See in particular pages 4–7 for discussion of water management structures.

Trench A: Kalaitzoglou et al. (2013), pp. 58–63; Lichtenberger et al. (2013), pp. 10–12.

Trench S: Kalaitzoglou, Lichtenberger, and Raja (Forthcoming-b).

In Gerasa, there is also evidence for cults, apart from that of Artemis, which were connected with water rites. These include the Maiumas festival (Welles, 1938, pp. 470–471, inscription 279) as well as the cult of Thea Epekoa Leukothea (Gatier, 1982, pp. 274–275, no. 4).

The paintings were studied by Kristine Thomsen in her unpublished PhD thesis with the title Urban Life in Jerash, Jordan: The Technological and Stylistic Development of Mortar, Plaster and Wall Paintings from Roman Times to the Middle Islamic Period from an Archeological and Geoarchaeological Perspective. The thesis was defended in May 2019.
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**How to cite this article:** Lichtenberger A, Raja R. Management of water resources over time in semiarid regions: The case of Gerasa/Jerash in Jordan. *WIREs Water.* 2020;7:e1403. https://doi.org/10.1002/wat2.1403