THE JARASH WATER PROJECT 2016 REPORT ON THE FOURTH FIELD SEASON

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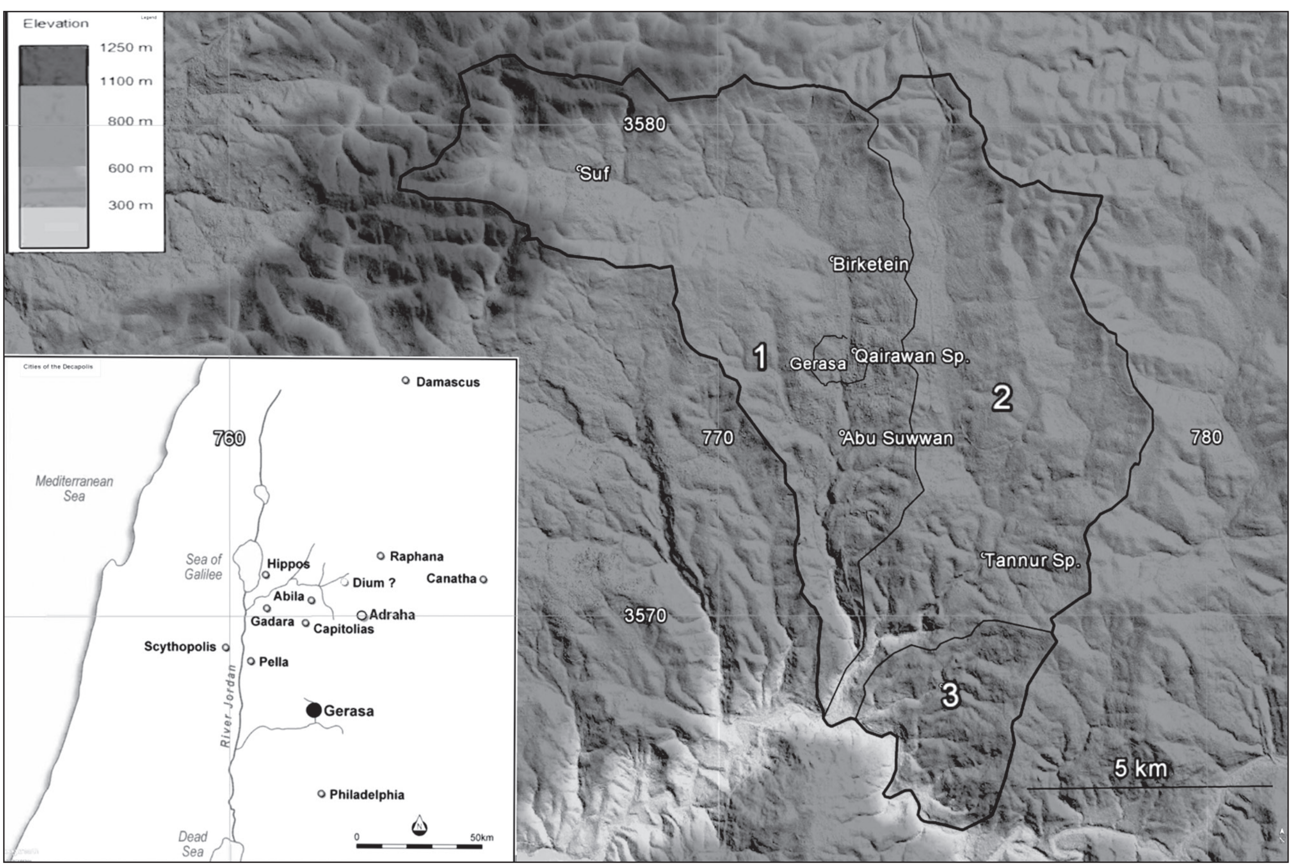
Introduction

The Jarash Water Project (JWP) is investigating the water-management system to Gerasa and its hinterland in the Hellenistic to Byzantine period (2nd century BC - mid 7th century AD). The 100 km² project area comprises the Jarash valley[1] and the neighbouring Majarr-Tannūr valley[2] (**Fig. 1**). The JWP study seeks answers to several fundamental research questions, including the sources of water supply for the city and its hinterland, the nature of the water distribution network and the period of its use. This report covers fieldwork conducted in the fourth and final field season between 8th May 2016 and 19th May 2016.

Previous field seasons were conducted in 2013, 2014 and 2015 (respectively Boyer 2017; 2018a; 2018b. Surface surveys identified



1. Study area and catchment boundaries on 5m digital surface model obtained from AW3D satellite: (1) Jarash valley; (2) Majarr-Tannūr valley; (3) South-eastern wadis. (©NTT Data, RESTEC/Image ©2016 CNES/Astrium).

1. From north to south, the Jarash valley comprises Wādī Sūf, Wādī ad-Dayr and Wādī Jarash.

2. This valley comprises Wādī al-Majarr and Wādī at-Tannūr (also known as Wādī ar-Riyāshī).

aqueduct and storage components of an extensive water-management system in the Jarash and lower Majarr-Tannūr valleys, primarily sourced from strong springs (Boyer 2016a; 2016b). The ancient water-distribution system to both rural and urban consumers generally comprised open canals cut directly into outcropping bedrock. However, the survey also recorded masonry canals and relatively short sections of aqueducts carried in tunnels. The limited application of archaeological excavation during the study has meant that the dating of water-related installations has relied on obtaining radiocarbon dates (C_{14}) from charcoal-bearing plaster or mortar lining these installations (Boyer in prepare). Few installations identified in the study have suitable charcoal-bearing plaster, the north-west aqueduct being a notable exception.

Research on cave sites west of the Jordan Valley (Bar-Mathews and Ayalon 2011; Vaks *et al.* 2010; Verheyden *et al.* 2008) has shown that speleothems can be important palaeoclimate proxy archives. To date, there is no published research on speleothems from the Ajlun Highlands, and JWP has initiated palaeoclimate studies on speleothem and tufa samples collected from sites in the Jarash valley in an attempt to fill this knowledge gap. Studies in Turkey and western Europe have found that carbonate sediment (sinter) commonly found lining Roman aqueducts can also be a useful palaeoclimate proxy archive (for example Passchier *et al.* 2016; Sürmelihindi *et al.* 2013), and in this context a separate palaeoclimate study is investigating the carbonate sinter from Gerasa's north-west aqueduct.

The 2016 field program included pedestrian surveys of selected areas to complete the identification of the visible hydraulic installations in key areas. Total-station surveying recorded additional site data at nine important locations in the Jarash valley with the assistance of Department of Antiquities (DoA) staff. The 2016 surface survey recorded twelve new archaeological sites (JWP181-192), bringing the total number of archaeological sites recorded in the four field seasons to 92, and revisited four previously recorded sites (JWP111, 125, 135 and 164). The surface survey focused on sites within the Jarash valley, with only two new sites recorded in the Majarr-Tannūr valley. While the surface survey successfully identified many new archaeological elements, housing and farm development activities limited visibility and access. These factors continue to be the major causes of the destruction of archaeological sites outside of the Jarash Archaeological Park.

The survey identified new aqueduct elements on the east side of Wādī ad-Dayr in the Birkatayn locality and several new spring sites, including a major relict spring site 150m north-west of Birkatayn reservoir that probably supplied the Birkatayn baths.

Contextual geoarchaeological observations made during the field survey contributed to the understanding of the area's landscape history and clarified the depositional extent of the (?) Pleistocene Jarash Conglomerate formation. Studies in the southern Jarash valley provided a relative dating sequence for the main fluvial events in this section of the *wadi*.

Objectives and Methodologies

The program built on the results of the three previous seasons with the aim of finalising the field component of the project. It had four main objectives:

1. To conduct a total-station survey of key archaeological sites identified in the study.
2. To carry out a purposive pedestrian field survey of selected areas identified from photographs and satellite imagery (ALOS World 3D and Pleiades) as being likely to yield information on the ancient water-management system and palaeolandscape.
3. To collect samples of mortar/plaster and carbonate sinter from key water installations for C_{14} dating and laboratory analysis.
4. To make geoarchaeological observations and collect geological materials for analysis.

As in previous seasons, the pedestrian survey focused on locating and recording archaeological sites related to water management. The procedure involved the recording of the archaeological elements at each site by means of a written description, physical measurements, colour digital photographs and sketches, with the location determined by hand-held GPS. The survey concentrated on discrete geographic sectors: in the city area, these included the eastern part of the walled city and on the hill slopes west of the Jarash Archaeological Park, while in the rural hinterland they included the hills west of the city, the Jarash valley and in the Majarr-Tannūr valley.

The 2016 program included the total-station surveying of nine sites selected because of the uniqueness of their archaeological features and the perceived risk of damage or destruction from new building construction or agricultural activities.

Results

Site Types

The focus on water-related archaeology limits the number of recorded site types. **Table 1** lists the archaeological elements recorded at the various sites and **Fig. 2** shows site locations. **Fig. 3** shows aqueduct alignments referred to in the report.

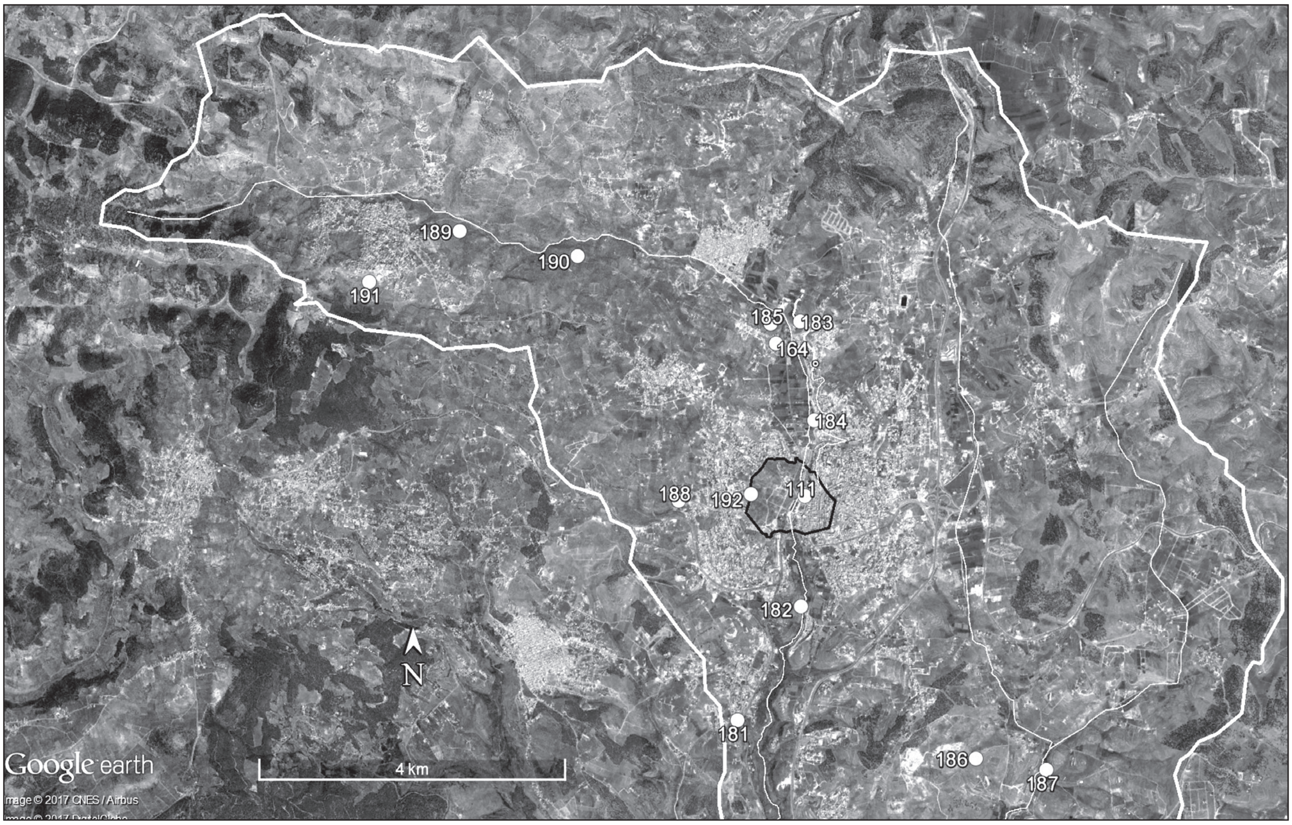
Aqueducts

Qayrawān Aqueduct

The only surviving above-ground section of the Roman aqueduct from Qayrawān spring (site JWP-111) was revisited, as a new stratigraphic profile had been temporarily revealed during new building construction adjacent to the substruction wall carrying Qayrawān aqueduct. Excavations associated with the new building had revealed that the full height of the substruction wall is *ca* 3.5m at this location. This wall is part of the same substruction wall previously recorded by Lepaon (2008: 65-67) in the excavation of the Small (Byzantine) East Baths (Lepaon 2008: 65-67) 10-15m to the south. No date for the Qayrawān aqueduct has been published, but it is likely to date to the same period as the monumental parapet wall at Qayrawān

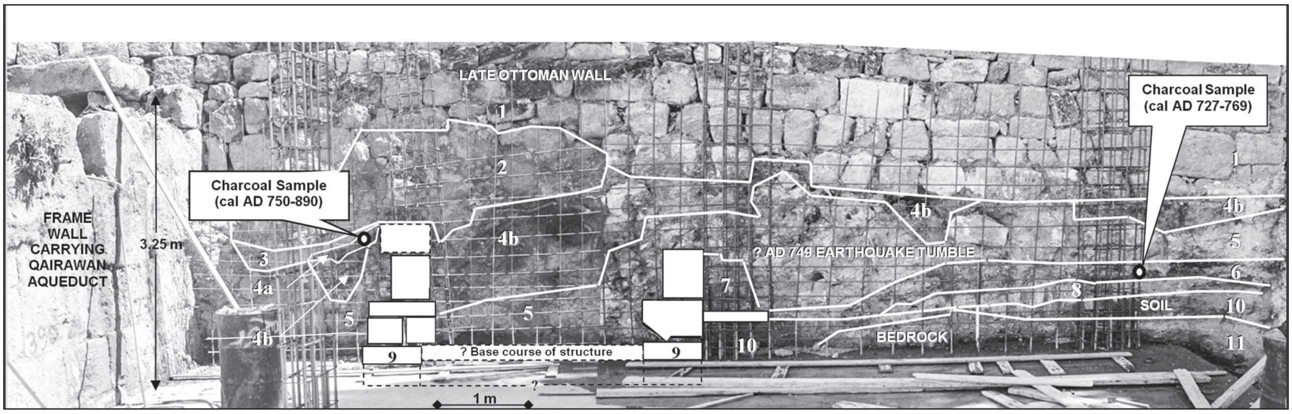
Table 1: Archaeological site details - Jarash Water Project, 2016 Field Season.

JWP_Site No.	Locus	lat (N)	long (E)	GPS Elev	Remarks
111	1	32.28055	35.89503	562	Masonry structure
125	1	32.30048	35.89516	642	Rock-cut canal
135	1	32.24370	35.92445	473	Water mill masonry canal(leat)
135	2	32.24383	35.92451	473	Masonry structure (foundations)
135	3	32.24383	35.92463	477	Masonry structure (foundations)
135	4	32.24355	35.92445	473	Masonry structure (?mill house foundations)
135	5	32.24350	35.92461	473	Masonry specus blocks
164	1	32.29841	35.89148	640	Rock-cut canal
164	1	32.29841	35.89148	640	Rock-cut canal
181	1	32.25473	35.88517	449	Spring
181	2	32.25450	35.88504	466	Spring
181	3	32.25419	35.88545	459	Spring
182	1	32.28055	35.89503	500	Rock-cut basin
183	1	32.30079	35.89502	646	Rock-cut canal
183	2	32.30091	35.89485	645	Rock-cut canal
183	3	32.30098	35.89481	644	Rock-cut canal
183	4	32.30119	35.89465	644	Rock-cut canal
184	1	32.28931	35.89655	589	Rock-cut canal
184	1	32.28931	35.89657	593	Rock-cut canal
185	1	32.30075	35.89080	649	Rural installation_olive/grape press
185	2	32.30075	35.89080	649	Spring/rock-cut waterfall
186	1	32.24947	35.91779	573	Rural installation_olive/grape press, rock-hole
187	1	32.24794	35.92759	507	Spring, basin
187	2	32.24794	35.92759	507	Rock-cut canal
188	1	32.28024	35.87761	596	Spring (kokosi)
188	2	32.28020	35.87774	603	Spring (kokosi)
188	3	32.28037	35.87841	596	Rural installation_olive/grape press
188	4	32.28037	35.87841	596	Rural installation_olive/grape press
189	1	32.31236	35.84802	848	?masonry canal
190	1	32.30913	35.86430	773	Rural installation_olive/grape press
191	1	32.30617	35.83532	1039	Spring
192	1	32.28088	35.88756	610	Masonry canal (Gerasa SW gate)



2. Location of sites recorded in 2016 (Satellite data: Google, DigiGlobe, CNES/Atrium and CNES Airbus).

3. Plan of aqueducts referred to in report (Satellite data: Google, DigiGlobe, CNES Airbus).



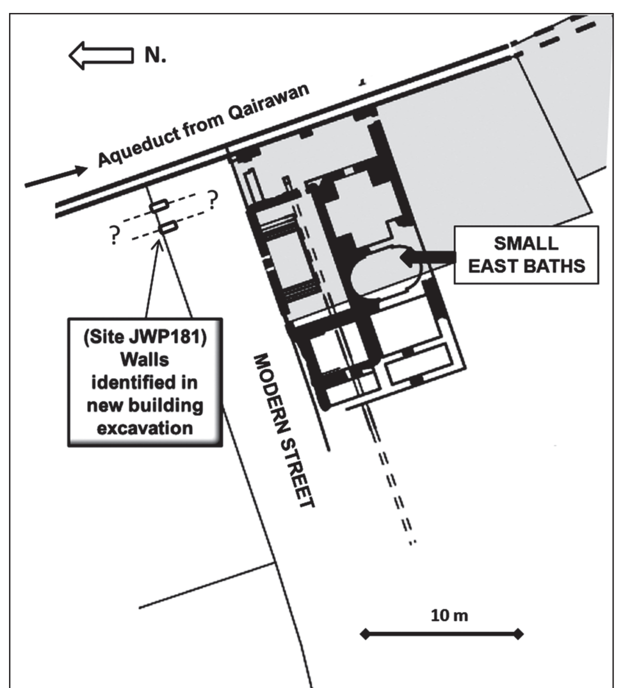
4. Site JWP111: Section showing masonry structure and stratigraphic contexts revealed in a modern building excavation adjacent to the Qayrawān aqueduct frame wall (looking south).

spring. The architecture of this parapet wall appears identical to the architecture of the parapet wall of the *nymphaeum* on the west side of the city, dated by inscription to the late second century AD (Welles 1938: 406, insc. 69).

The 10m long south wall of the building excavation revealed a *ca* 1.5m high, well-layered stratigraphic sequence below a stone wall of late Ottoman (Circassian) date. The section exposed two parallel walls of dressed masonry 1m high, part of a 3.65m wide structure aligned north-south (**Fig. 4**) lying on a (?) masonry floor. The building was probably constructed on Jarash Conglomerate bedrock, and this bedrock was exposed at the western end of the section. The coarse tumble layer in context 5 contains dressed building blocks and is underlain by context 6, which is rich in charcoal dated to cal AD 669-769 (95.4% probability) and overlain by a thick charcoal and ash layer (context 4). A C_{14} date of cal 710-890AD (95.4% probability) was obtained from charcoal in context 4a, making it likely that the coarse tumble layer (and possibly the overlying charcoal and ash layer) is related to the 749AD earthquake. The property owner reported that a watercourse (still carrying water) had been observed during building-site excavation prior to the laying of the concrete slab for the new building, but its function and destination are unknown. This watercourse ran roughly parallel with the Qayrawān aqueduct and passed under the masonry building. The masonry structure may form part of the Small East Baths, which lie *ca* 10m to the south of the stratigraphic section (**Fig. 5**). Lepaon (2012: 294) dated these baths to the mid-fourth century AD.

Site JWP164

The rock-cut aqueduct (SW02) at site JWP164, 150m south-west of Birkatayn, was revisited and excavated to expose the cross-sectional profile of the soil-filled canal. Excavation of the aqueduct at its northern end revealed two stages of canal construction. The first stage involved the cutting of a *specus* up to 0.85m wide and 0.40m deep into an exposed east-facing rock slope. The second stage involved the deepening of the western side of this *specus* to create a separate *specus ca* 0.10m deep, and the construction of a *ca* 5cm high wall of lime-rich mortar on the east side of this new *specus*. The



5. Site JWP111: Plan showing proximity of masonry structure to nearby Small East Baths (plan modified from Lepaon 2008: fig. 11).

maximum wettable sectional area of the deeper *specus* is around 30% of the equivalent area for the first, shallower *specus*. While this was presumably done to improve flow velocity in low-flow conditions, it is not clear if this was done to accommodate seasonal fluctuations in spring discharge or was a response to an overall reduction in spring discharge. Two small (overflow?) outlets have been cut into the eastern wall of the easternmost canal, at a point where the original *specus* had been widened (**Fig. 6**).

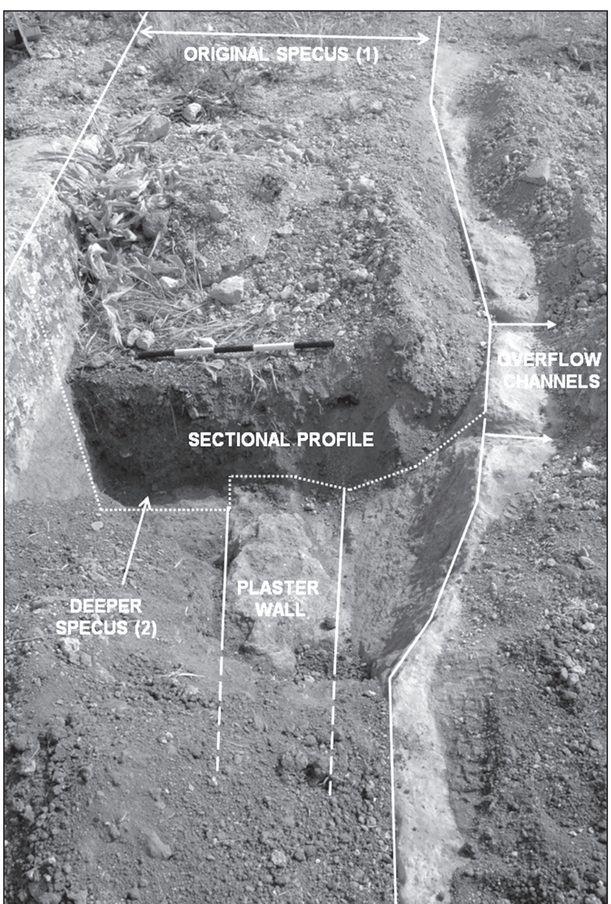
Aqueducts from (as-Sawdā') Spring

Two ancient canals were supplied from a spring (as-Sawdā') located 400m north-east of Birkatayn reservoir at site JWP183. The upper canal from this spring (SE06) was partly rock-cut and partly constructed on a raised bank at an elevation of *ca* 649m (**Fig. 7a**). Details preserved in several rock-cut sections show that this canal was constructed with a double *specus*, the floor of the western *specus* being 13cm lower in elevation (**Fig. 7b, c**). A similar double-*specus* profile was observed in the lower canal (SW05 - site JWP125), constructed at an elevation 7m below and 25m to the west of the upper canal, where the difference in elevation of the *specus* floors is also 13cm (**Fig. 7d, e**).

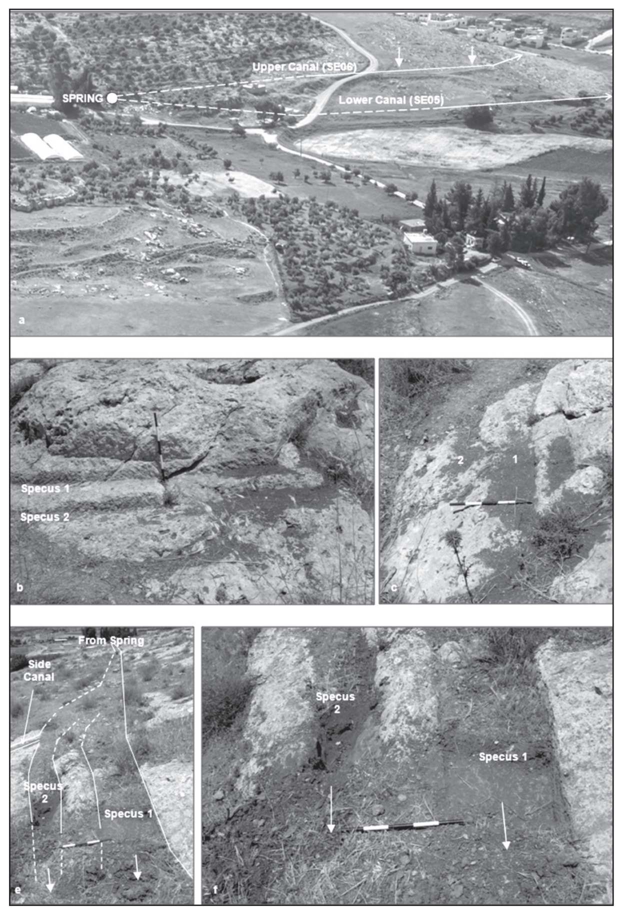
Springs

Spring Cascades and Natural Fountains

Five new spring sites were recorded in 2016. In all cases, some or all of the observable spring outlets lay within or above a bedrock scarp, and water discharging from these outlets would have formed natural curtain cascades and fountains when the spring was active (**Fig. 8**). Rock-cut modifications to enhance or concentrate water flow were found at the majority of spring sites recorded in 2016 and are a common fea-



6. JWP164: View of the two specus, separated by a low plaster wall, and small overflow outlets (looking north; scale bar 0.5m).



7. Rock-cut aqueducts supplied from as-Sawdā' spring: (a) Oblique aerial view (looking south-east) showing relict bank supporting upper canal SE06 (arrows) from spring (Photo courtesy of APAAME: APAAME_20130427_DDB-0558, Photographer, D. Boyer); (b) and (c) Site JWP183, showing the double specus on upper canal SE06; (d) and (e) Site JWP125 showing the double specus on lower canal SE05 (scale bar 0.5m).

8. Relict spring cascade at site JWP191 (looking north).

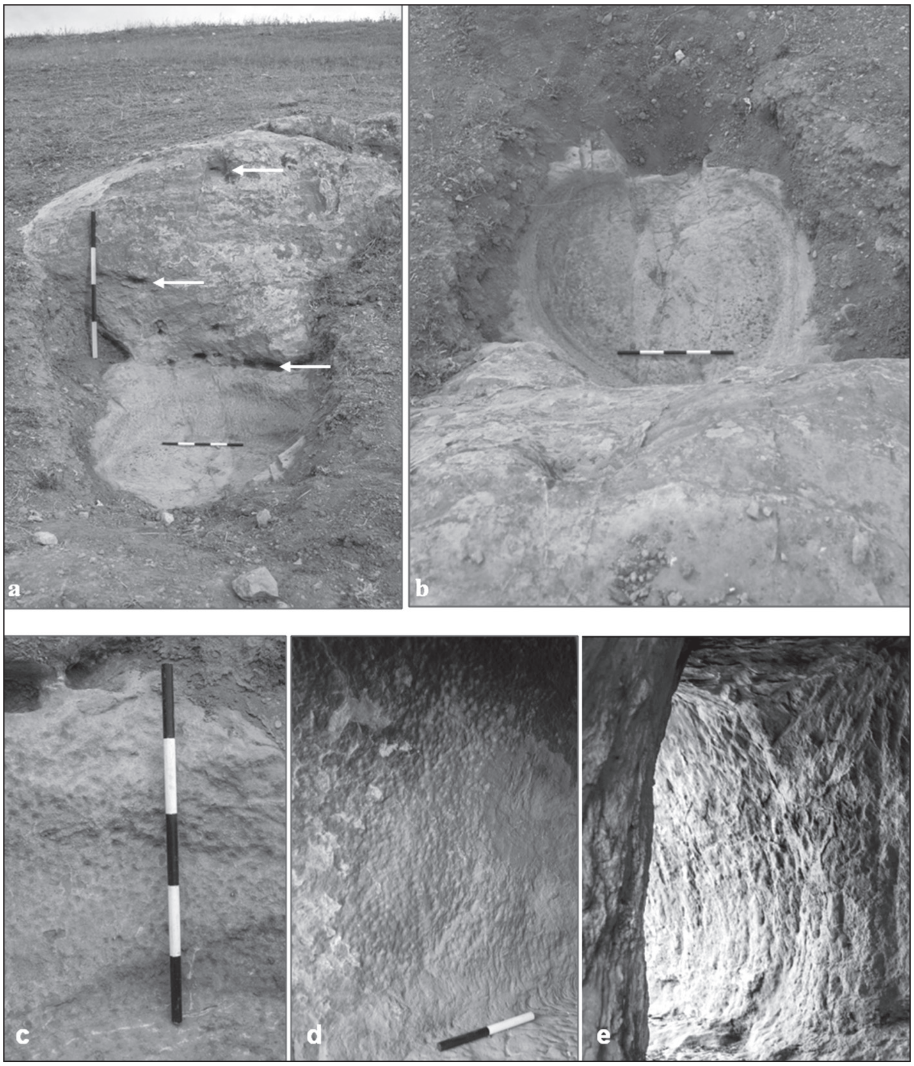

9. Site JWP185: View (looking west) of natural spring cascade with rock-cut channels (arrows) that directed spring-water flow over the 3m high scarp.

ture of spring sites in the Jarash valley. Modifications recorded in 2016 included the cutting of channels to concentrate the flow of water over the top of the cascade to form individual fountains or to direct water flow down the face of the scarp into small catchment basins (sites JWP181, 185, 187 and 191), and the cutting of catchment basins below natural fountain outlets (site JWP182). These modifications would have had the dual effect of dramatising the appearance of the site and making it easier for the water to be collected for domestic use. Modifications to re-direct flow are well preserved at the major relict spring recorded at site JWP185, located on a hill slope 250m north-west of Birkatayn, where at least four channels were cut into the top of the 3m high cascade (**Fig. 9**). This spring may have supplied the Birkatayn baths and may have been a source for the large aqueduct recorded at site JWP164.

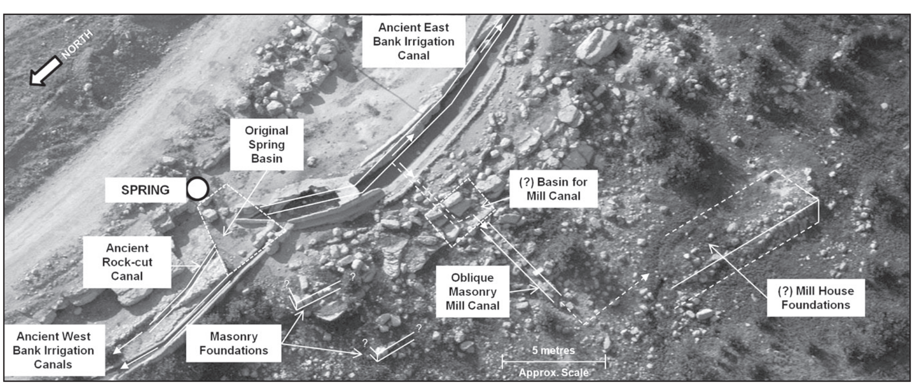
Surveying at the southern end of the large (0.7 ha) relict spring complex at Ficus springs in Wādī Jarash 1km south of the city identified a small, well-preserved, natural fountain and rock-cut catchment basin exposed in a looters hole on the *wadi*'s west bank (site JWP182). Uniquely, the basin surface has a distinctive coarsely 'pecked' finish compared to the usual 'picked' finish found in the tunnel walls and canals at Ficus springs. The picked finish is attributed to the use of a pointed iron pick of '*escoude*' type (Bessac 1988: 37). The coarsely pecked finish of the basin closely resembles the pecked finish observed on the interior surfaces of (?) Bronze Age rock-cut tombs preserved in the Kurnub Sandstone cliffs overlooking the Jarash bridge crossing the Zarqa River (**Fig. 10)**. While this raises the possibility that the basin may date to the Bronze Age, the present evidence does not preclude an earlier or later construction date. Evidence from Petra, for example, shows that pecked finishes on sandstone surfaces were a common feature in Nabataean architecture (Rababeh 2005: 93-95). The site is located on the eastern edge of the terrace that contains the abū aṣ-Ṣuwwān Neolithic 'mega-site' (al-Nahar 2010, 2013) and 550m north of the hilltop Early Bronze Age *tall* of Khirbat Khālid (Hanbury-Tenison 1987: 156; Leonard 1987: 354).

Buildings at Spring Sites

While it is likely that some form of building was originally constructed at each of the larger spring sites in antiquity, very little evidence of these buildings has survived. Surveying in 2016 revealed evidence of building foundations at at-Tannūr spring, which is the strongest spring in the Majarr-Tannūr valley and supplies an extensive irrigation network (**Fig. 11**). The main ancient structure is a water-mill complex, comprising an oblique mill canal (leat) and the foundations of a building thought to be the mill house. Water was supplied to the leat from the spring via a basin. While the best-preserved horizontal watermills in the present landscape are watermills of the *arubah* penstock type with a horizontal leat (Avitsur 1960: 40), there is evidence that horizontal watermills with a slanting or oblique leat (oblique chute) were once a common feature of the historic landscape - although rarely preserved today. The 1m wide masonry wall carrying the oblique chute at Tannūr spring is the best preserved in the study area, although hard to discern amongst the stone tumble on the slope below the spring (**Fig. 12**).



10. Ficus springs: (a) Natural fountains (highlighted) and catchment basin cut into Kurnub Sandstone at site JWP182 (scale 0.5m); (b) Vertical view of catchment basin at site JWP182 (scale 0.5m); (c) Detailed view of coarse 'pecked' finish on the basin surface at site JWP182 (scale 0.5m) ; (d) View inside (?) Bronze Age tombs at az-Zarqā' R. / Wādī Jarash junction, showing coarse-pecked finish (scale 20 cm); (e) Coarse 'picked' finish on tunnel wall, site JWP146 Ficus springs.

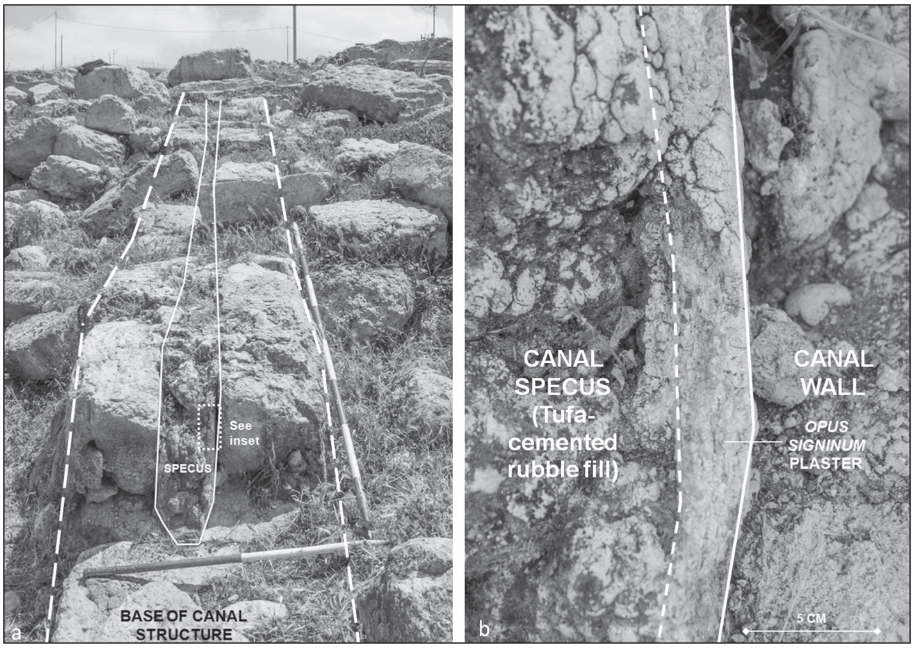


11. Tannūr spring (site JWP135): Aerial view showing main structural elements (Photo courtesy of APAAME; APAAME_20130428_REB-0064; Photographer R. Bewley).

Blanc and Genequand (2007: 304) considered that oblique chute mills were introduced in the early Islamic period, and provisionally dated several of these mills in Syria to the early 8th - 9th centuries AD. The *opus signinum* plaster lining the *specus* of the oblique chute at Tannūr spring may suggest a pre-Islamic date, although Wilson (2003: 129) noted that the use of this typical Roman plaster continued into the early Islamic period in North Africa and Turkey. Radiocarbon dating of charcoal in this plaster will clarify the construction date.

al-Majnūnah Dolmen Field

A small dolmen field on the edge of al-Majnūnah village was recognised by DoA representative Mr. Adnan Mujalli while surveying in the 'Ayn ar-Riyashah area. The dolmen lo-



12. Tannūr spring (site JWP135): Oblique chute canal: (a) view upslope towards spring (horizontal pole 1m); (b) Detailed view of opus signinum plaster lining canal specus.

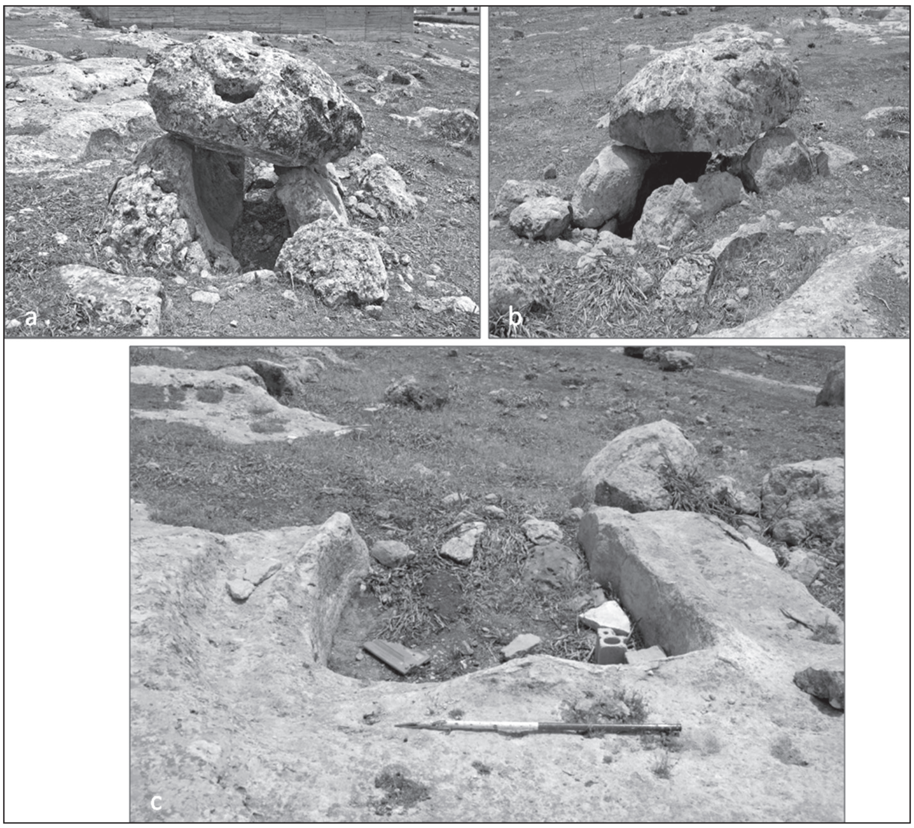
cality is shown on a plan by Sapin (1992: fig. 2), but no description has been published. Although not related to water management, the site was briefly recorded during the Jarash Water Project survey as it is under threat from new housing.

The site covers roughly 0.1ha, although a detailed survey may prove it to be larger. It is located between two houses on the west side of the village, about 0.5km west of ʻAyn ar-Riyashah. Only one dolmen retains its capstone and side megaliths (**Fig. 13a, b**), however the burial floor of this dolmen is a distinctive, smooth bath-shape cut in the bedrock, and many similar features - presumably representing dolmen sites robbed of their megaliths - were observed in close proximity. One of these dolmen floors is rectangular in plan and may represent a multiple-burial site (**Fig. 13c**). The site lies close to western edge of the main dolmen fields in the Majarr-Tannūr valley. However, the site is under threat from new housing construction and warrants a detailed study and preservation.

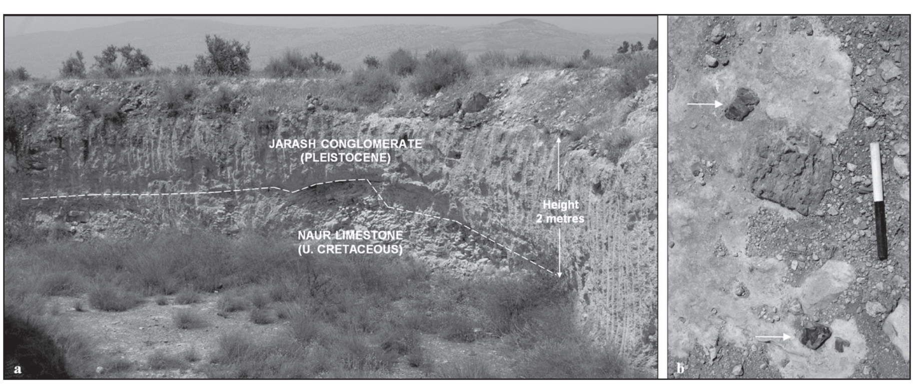
Geoarchaeological Studies

Geoarchaeological surveys conducted by the Jarash Water Project in 2014 and 2015 recognised a new debris-flow type of geological formation at a number of locations in the Jarash valley and, to a lesser extent, in the upper Majarr-Tannūr valley. It has been tentatively assigned a Pleistocene age based on a comparison with the Pleistocene Dawqarah Conglomerate (Parenti *et al.* 1997: 19) in the upper Zarqa valley (Boyer 2017; 2018a–2018d). Similar surveys conducted in 2016 extended the depositional limit of the formation in the Jarash valley to around 8km^2, and also identified exposures of the formation in the lower Majarr-Tannūr valley (**Fig. 14a**), including one locality west of al-Majnūnah village where the formation contains flint cobbles (**Fig. 14b**). This potential flint source may have been a factor in the location of the Neolithic settlements adjacent to the nearby perennial springs at ar-Riyāshī (Hanbury-Tenison 1987: 154 site 15) and al-Mītah (Leonard 1987: 354 site 27). Similarly, the abū aṣ-Ṣuwwān Neolithic ʻmegasite' south of Jarash is also located adjacent to Jarash Conglomerate bedrock containing flint cobbles that are likely to have been a source of raw material for a local flint industry (Baker and Kennedy 2011: 457).

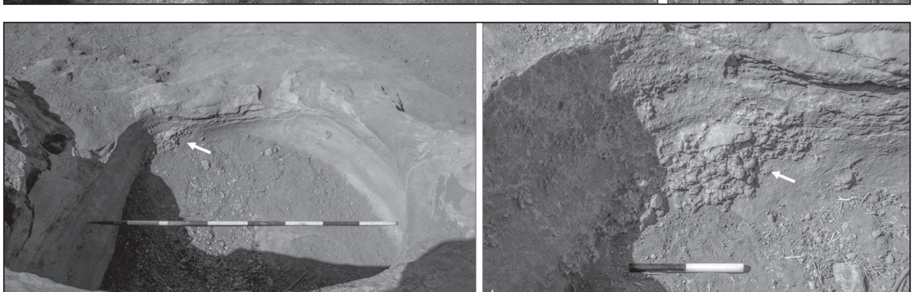
Investigations at Ficus springs, 1km south of Jarash, revealed evidence of a multistage landscape history of this part of the Jarash valley. Studies are incomplete, but provisional findings indicate two (degradation) phases of *wadi* incision followed by a more stable phase, during which water-related installations (well-preserved fountain catchment basins and probably adjacent rock-cut canals) were constructed. Graffiti (Greek?) preserved *in situ* on a western cliff face probably also date to this phase. Debris flows subsequently filled the *wadi* and buried at least some of the water installations, as attested by remnant conglomerate cemented to the floor of a fountain's catchment basin on the east bank (**Fig. 15**). These later debris flows are tentatively dated to the pluvial events of the Byzantine period that peaked in 6th and 7th centuries AD (Izdebski *et al.* 2016: 197), and may be comparable to the debris flows recently identified at Abila that have been dated to the same period (Lucke and Schmidt 2017). The later debris flows at Ficus springs appear superficially similar to the older Jarash Conglomerate debris-flow sediments outcropping on the upper slopes of the *wadi*'s west bank at the



13. al-Majnūnah Dolmen Field: (a) and (b) Dolmen complete with side megaliths; (c) Rock-cut floor of large dolmen that may reflect a multiple burial (1m pole).



14. Jarash Conglomerate in lower Majarr-Tannūr valley, west of al-Majnūnah village: (a) Contact of Jarash Conglomerate with underlying Upper Cretaceous Naur Limestone in quarry; (b) Flint cobbles (arrowed) in exposed 'pavement' of Jarash Conglomerate (scale 20cm).



15. Ficus springs, site JWP146, showing debris-flow conglomerate cemented to the floor of an earlier fountain catchment basin: (a) Vertical view of catchment basin; (b) Detailed view of cemented conglomerate on basin floor.

Bāb ʻAmmān locality: they comprise reworked rounded clasts from the older debris-flow material mixed with soil, but are less indurated (**Fig. 16**). Taken together with evidence of the debris flows occupying channels aligned orthogonally to the present *wadi*, it appears that the debris flows were associated with landslips along the west bank of the *wadi*. The massive, *ca* 400m long landslip on the west bank evident in the landscape between Ficus springs and the city could have contributed much of the material for the debris flows, but this landslip event has not yet been separately dated (Boyer 2018c: 236, fig. 10b). A subsequent degradation phase removed the debris-flow sediments from the *wadi* bed and exhumed the buried water installations. The final aggradation phase saw the deposition of *wadi* sediments on the *wadi* bed, and this is the current state of fluvial processes in this section of Wādī Jarash.

Acknowledgements

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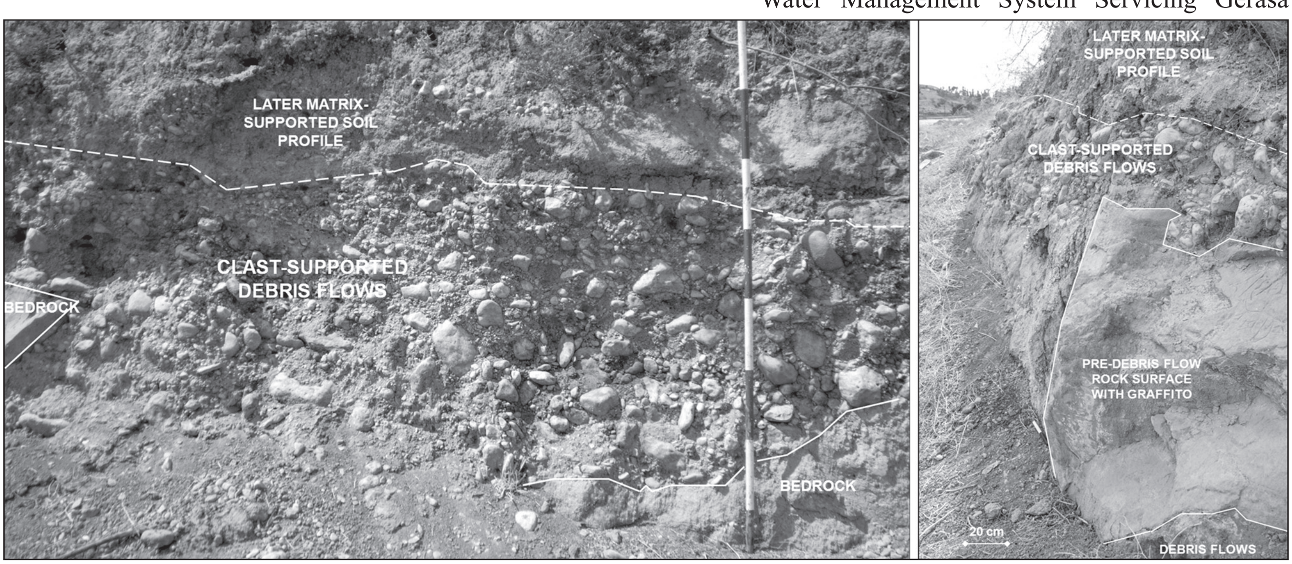

16. Ficus springs: Sedimentary profile exposed on west bank of wadi (2m pole).

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