The Annual of the British School at Athens, **118**, 2023, pp. 349–397
doi:10.1017/S0068245422000156

THE ROMAN AQUEDUCT OF KNOSSOS, A MODEL FOR NINETEENTH-CENTURY AQUEDUCT DESIGN

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In this paper, we present findings from a field inspection of the Knossos aqueduct undertaken in 2019. A key contribution of our fieldwork was the architectural identification of the Roman channel underlying the nineteenth-century wall of the Ottoman-Egyptian aqueduct supplying Iraklio. While reuse of the Roman aqueduct in the nineteenth century was known from historical reports, the structural overlap has never been identified in the field or documented archaeologically, until now. We recorded the Roman channel lined with opus signinum *running along the base of the nineteenth-century aqueduct's wall between Fundana and Spilia. Through this realisation in the field, we were able to establish diagnostic styles of masonry for both periods. Our architectural distinction between the overlaid aqueducts allowed us to integrate previously disarticulated components of the later system, like the reused Roman tunnel at Skalani and the nineteenth-century bridge at Spilia, into an integrated Ottoman-Egyptian water supply for Iraklio. As we approached Knossos from Spilia, we were also able to identify the point at which the Venetian aqueduct supplying Iraklio converged with the Roman system. Consequently, our 2019 fieldwork not only mapped the length of the Roman aqueduct supplying the city of Knossos but also that section of the nineteenth-century Ottoman-Egyptian aqueduct of Iraklio built directly over it and a shorter tract of the Venetian aqueduct of Iraklio that either ran alongside it or was, in turn, itself partially overlaid by the nineteenth-century system.*

INTRODUCTION

In November 2019, the authors conducted a field inspection plotting the route of the Roman aqueduct supplying Knossos using a handheld Trimble GPS station and a series of 1:5000 Hellenic Military Geographical Service Maps ahead of a planned drone study. The subject of the 2019 field inspection was the long-distance water supply for Roman Knossos, mapping its route and documenting any measures taken to secure the delivery of this water to the Roman city. Our fieldwork builds on solid foundations laid by Strataridaki, Chalkiadakis and Gigourtakis (2009), who conducted a partial survey of the Roman aqueduct, locating the water conveyance tunnel at Skalani. We provide the first GIS map of the complete route of the Roman aqueduct, adding both elevations and physical length to the aqueduct's known trajectory. We mapped, for example, a previously undocumented 2.19 km stretch of aqueduct running from below the tunnel exit at Ampela to the upper reaches of the Spilia Spur (i.e. Walking Route 2, henceforth WR2, on Fig. 1).[1]

[1] The following abbreviations are used in this paper:

ΓΥΣ	Χάρτες της Γεωγραφικής Υπηρεσίας Στρατού (Hellenic Military Geographical Service Maps [HMGS])
amsl	above mean sea level
IAA	Ιστορικό Αρχείο Αρχανών (Historical Archive of Archanes)
KS	Knossos Survey (Hood and Smyth 1981) catalogue number
KULP	Knossos Urban Landscape Project
TAH	Τουρκικό Αρχείο Ηρακλείου (Turkish Archives of Iraklio – Vikelaia Municipality Library)
WR	Walking Route
WSB	Kenneth Wardle's Small Bath (Area C)
WLB	Kenneth Wardle's Large Bath (Area H)

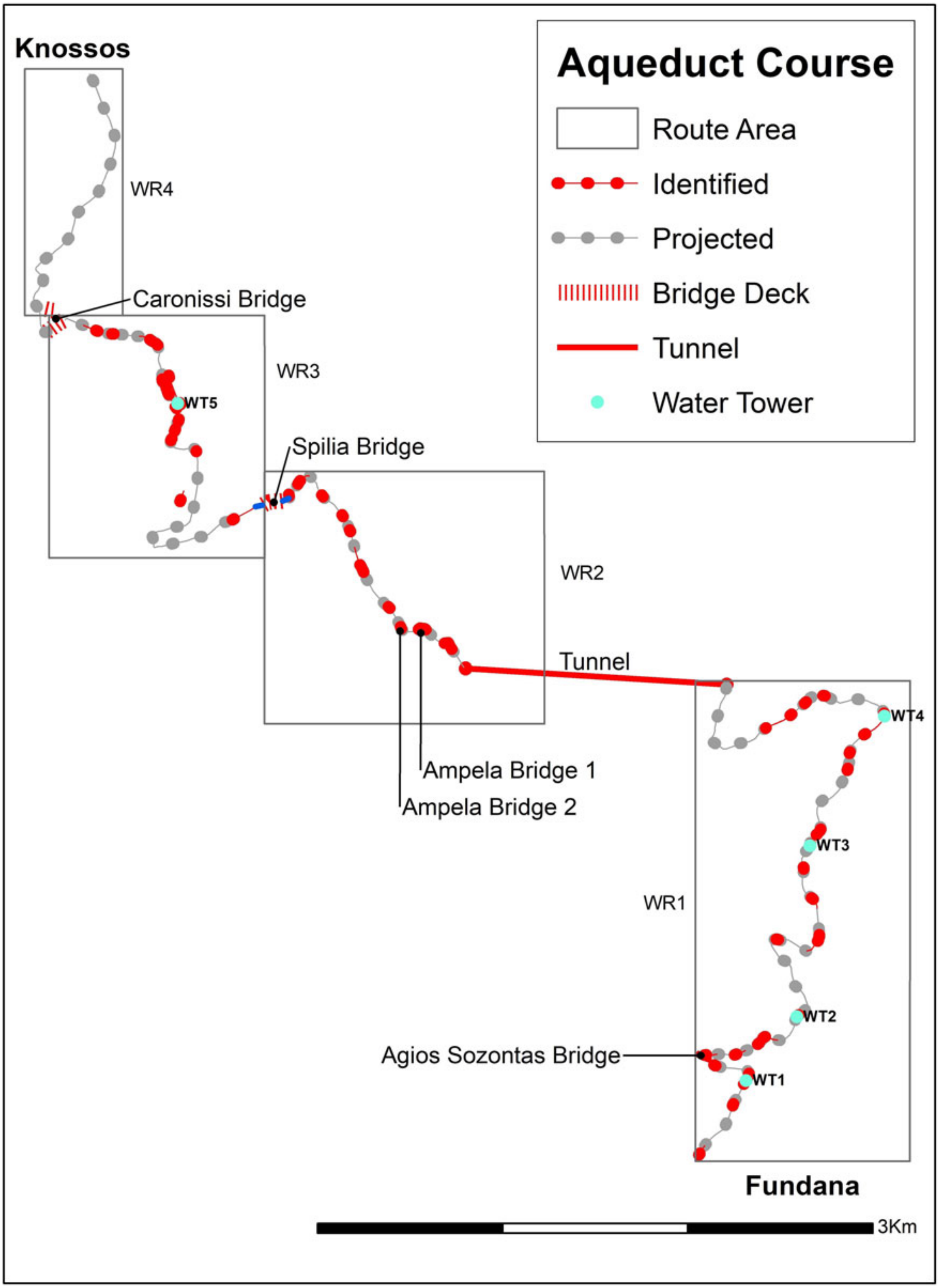

Fig. 1. Aqueduct course showing Walking Routes.

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

On the Roman aqueduct's final approach to Knossos, from west of the Spilia Bridge, our documentation benefitted from the fieldwork of Susan Walker and Richard Jones, undertaken in 1976 as part of the 1981 Knossos Survey (henceforth KS). They reported the Roman aqueduct at the following positions (listed in reverse order from west of the bridge): KS 353–346, 319, 318, 217, 191, 188, 168 and 160, fig. 31. With a few notable exceptions, these tracts were re-identified in 2019; we could not reproduce, however, the circumnavigation of the Lower Gypsadhes plotted by the 1981 KS, as tracts KS 347, 346 and 318 were not located in 2019, which was perhaps to be expected as they were all originally reported as sub-surface features.

The route as plotted in 2019

The route of the free-flow aqueduct systems, from Fundana to Knossos, runs from the Fundana spring to the tunnel entrance at Skalani (crossing at least one bridge en route) (see WR1 on Fig. 1), through a Roman tunnel which extends over 1 km from Skalani to Ampela; from below Ampela, crossing two small bridges on a roughly northerly route before rounding the Spilia Spur (WR2); the channel then crossed the Katsambas River, turning north to follow the eastern contours of the Upper Gypsadhes hill before approaching Caronissi (WR3); from there, the aqueducts reportedly track the country road northwards towards Knossos village (Bougada Metochi) (WR4 on Fig. 1).

A note on gradient

Through careful planning, the Roman aqueduct supplying Knossos used the natural terrain to attain its necessary height, largely dispensing with the need to construct elevated walling; a measure which would have reduced costs and facilitated speedy completion. The walls of both systems supplied by the Fundana spring, the Roman and Ottoman-Egyptian, were not unduly elevated and were constructed using the natural stone encountered en route. The inverted siphon bridge at Spilia represents a marked departure, where this monument to structural engineering dominated traffic along the roadways and the Katsambas river valley running downstream from Epano Archanes.

Gradients along aqueducts are never uniform over their entire lengths; the Eifel aqueduct has slopes ranging from as low as 0.1 per cent to drops as steep as 10 per cent (Hoffman et al. 2019, 2354, fig. 3). Hodge (1992, 218), however, observed 'usual' average gradients between 0.15 per cent and 0.3 per cent. The slope from Fundana to the higher contours of Spilia is 0.2 per cent or 0.1° (with a run of 8.24 km and a drop of 14 m, or a drop of 1 m every 588 m). This means that the Roman aqueduct operates on an average slope of 0.2 per cent for about 66 per cent of its length of 12.42 km.

The Roman aqueduct of Knossos can perhaps be viewed as an aqueduct running on two different levels, with a considerable drop separating the two, identified at Spilia. A lower course starts directly west of the crossing at Spilia at a level of 137 m above mean sea level (henceforth amsl) and runs to just above Knossos village (Bougada Metochi) along a contour of *c.* 115 m amsl (although it is difficult to track on its final leg). Along this lower route of just over 4 km, the gradient may be 0.55 per cent (0.3°), or 1 m every 181 m.

The drop along the Roman aqueduct's entire length of 12.42 km is *c.* 60 m, and if the slope were consistent, this presents an average slope of roughly 0.48 per cent (or 0.28°), meaning that the aqueduct would drop approximately 1 m in every 207 m. Lewis (2001, 173, table 9.1) presented a comparable average slope for the aqueduct of Corinth at 0.5 per cent while that at Mytilene measured 1 per cent. But if the Roman aqueduct of Knossos has an overall slope of 0.48 per cent, almost half of the fall occurs at Spilia.

Background

Before proceeding, a basic definition of an aqueduct is useful for understanding our survey methodology and our approach to our field study. An aqueduct is essentially an architectural scaffold to facilitate hydraulic movement directed to a certain point at a sufficient height. Its

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ingenuity lies not in its monumentality but in its functionality. Roman aqueduct systems operated on the premise of constant hydraulic motion whereby movement was sustained by gravity. This gravitational movement could be interrupted, but once resumed, followed the same gravitational principles. An aqueduct's functional design is closely correlated with its associated geology and orography and it frequently forms a seam within the natural contours of the terrain. Aqueducts built along valley contours afford the easiest, most economical and rapidly executed constructions, as they avail themselves of the naturally gently sloping valley contours to maintain their required height. Valley contours running between the water source and the site to be supplied are ideal for aqueduct construction, and in this regard, the topography of Crete lends itself to the construction of gravity flow systems along valley contours (Kelly 2006, 320). The natural declivities within the Cretan landscape facilitated the construction of cost-effective low-profile aqueducts to convey water from numerous upland springs to low-lying (or at least, lower-lying) Roman cities.

The Roman aqueducts of Crete generally consist of contour channels supported on low-profile walling descending gently along river valleys. Second storeys have only been put forward for two Roman aqueduct bridges in Crete: the bridge to the north of the acropolis at Gortyna (as tentatively suggested by Taramelli 1902, 136–7) and at Xerokamares 2 along the Chersonisos aqueduct (Oikonomakis 1986, 74). Equally, water conveyance tunnels have only been securely identified along four aqueducts on Crete (Knossos, Chersonisos, Eleutherna and Polyrrhenia), of which that serving Knossos is by far the longest (see Table 1). In Crete, whenever possible, meandering contour-line construction was favoured over the extensive bridging and tunnelling otherwise required for more direct courses. In 2019, our walking route tracked the trajectory of the Roman aqueduct of Knossos from the Fundana springs to the upper village of Knossos (Bougada Metochi) (Fig. 1), and despite the direct distance of about 6.5 km from source to destination, the Roman aqueduct's trajectory measured 12.42 km, meandering along the valley contours to maintain its functional gradient.

The reuse of the Roman aqueduct

The historic record documents that when Crete had been ceded to Egypt (1830–40), Mehmet Ali (Ottoman governor of Egypt 1805–48) commissioned the construction of an aqueduct delivering the Fundana spring water to Iraklio. This project was completed under the supervision of Mustafa Naïli Pasha (Giritli Mustafa Pasha). John Bowring, the English Consul in Egypt, officially reported that construction was underway in 1838 (Bowring 1840, 162). It is relevant that construction on the nineteenth-century aqueduct was described as 'reconstruire' by Raulin (1867, 58) and again as repairs and refurbishments by both Ralegh Radford (1937, 6 n. 10) and Rashed (1978, 113) "ἐπεσκευάσθη ἢ μάλλον ἀνεκαινίσθη" ('it was built or rather refurbished'). Rashed specified that the repair work was carried out by the Egyptian army, although she attributed the original work wholly to Morosini.[2] In Bougie/Saldae in Algeria a similar reuse has been documented, where the city's Roman aqueduct, including its tunnel at El Habel (east of the Roman arcade at Ifran, Toudja), served as a type of blueprint for an aqueduct built in 1895/6 by the French army stationed there (Cuomo 2011, 157–8 n. 76). In 1896, the Roman inscription of Nonius Datus was fitted with a new panel listing both the civic administrators and the military engineers responsible for the new aqueduct, and the inscription was unveiled in its new location, outside of the townhall in Bougie, during the aqueduct's inauguration (Cuomo 2011, 158).

We see the reuse of civic aqueduct trajectories at other major centres on Crete. Repair to sections of the Roman aqueduct of Gortyna, notably its inverted siphon bridge, points to its continued (re)use into the Late Antique period (Giorgi 2016, 63–5). Other overlays were

[2] Rashed 1978, 113; Spanakis 1981, 92; 1990, 48; Strataridaki, Chalkiadakis and Gigourtakis 2009, 4 n. 30; Chalkiadakis 2012, 460. Spanakis reported that Anastasios Soulis attributed the work to the Venetian period while Ioannis Libritis believed it to be Roman (Spanakis 1981, 24 n. 21; Strataridaki, Chalkiadakis and Gigourtakis 2009, 4 n. 27).

Table 1. Water conveyance tunnels mentioned in the text (listed in descending order of tunnel length).

City supplied and construction date	Water tunnel location	Tunnel height	Tunnel width	Tunnel length	Source of information
Athens (Hadrianic)	Olympic Village 2004, foothills of Parnes – Agios Demetrios Church, Ampelokipoi	1.6 m	0.70 m	17.8 km	Chiotis 2018, 70, 77–8.
Knossos (2nd century AD?)	Skalani–Ampela	1.75–2 m	0.75 m	1050 m (1.005 km)	Amanda Kelly, personal observation; for the length, see Spanakis 1981, 24, 92 and Strataridaki, Chalkiadakis and Gigourtakis 2009, 2 pls 8 and 9, 4 n. 29.
Saldae/Bougie (Algeria) (mid-2nd century AD)	El Habel (east of the Roman arcade at Ifran, Toudja)	3 m	0.60–0.80 m	560 m	Laporte 1996, 720, 725 n. 60.
Nicopolis (earliest date, Neronian)	Kokkinopilos Tunnel	3–4 m	?	400–500 m	Zachos and Leontaris 2018, 35, 45; Lolos 1997, 304.
Chersonisos (Roman)	Soros Hill	3 m	1.80–2.10 m	200 m	Oikonomakis 1986, 52, 56, 61.
Thessaloniki (Roman)	Hortiatis Qanat	1.5–1.6 m	0.56–0.75 m	74 m	Manoledakis 2018, 55–7.
Polyrrhenia (Classical or Hellenistic)	Tunnel 1, SW of the village	2 m	0.80 m	>65 m–?	Voudouris et al. 2013, 1332; Markoulaki and Christodoulakos 2018, 99.
As above	As above	1.50 m	1 m	As above	Thenon 1867, 421.
As above	As above	1.2 m	0.70 m	As above	Pashley 1837, II.48.
Polyrrhenia (Classical or Hellenistic)	Tunnel 2, SE of the village	2.30 m	1.35 m	unknown	Thenon 1867, 421.
Eleutherna (Roman)	Anemomylos, Sector II	2–3 m	2 m	40 m	Sarris et al. 2015, 695.

Fig. 2. Roman channel (the Roman horizon marked by arrows) along base of the nineteenth-century wall, in Artemis Kokkinou's garden.

detected along the later aqueducts at both Chania and Rethymno (Gerola 1932–40, 28 and 33; Androvitsanea 2018) but also probably occurred at Souia and Axos.[3]

In 2019, our fieldwork identified the Roman channel underlying the nineteenth-century aqueduct's wall elevations along much of its length. For example, as the aqueduct approaches the tunnel at Skalani, the Roman channel is visible protruding from the base of the nineteenth-century aqueduct wall, where the Roman horizon rests 40 cm below the top of the later wall. The Roman character of this underlying construction was confirmed by thick coatings of *opus signinum* lining the channel, observed sporadically from Fundana to Spilia, but perhaps best demonstrated along the base of the wall in Artemis Kokkinou's garden, just north-west of Ampela Bridge 2 (marked in WR2 on Figs 1 and 2) and along the upper north-west slope of the Spilia Spur, overlooking the Spilia Bridge from the east (Fig. 3).[4] The Roman channel effectively served as a footing for the nineteenth-century aqueduct wall and provided a reference point for the additional height needed to support the later water channel while also serving as a blueprint for its trajectory. The later construction clearly damaged the Roman aqueduct, exposing its central channel. In many sections, only the *opus signinum* coating of the Roman channel survives, and the Roman wall is missing below this horizon (Fig. 3). This survival points to both

[3] Gerola 1905, 81. A more recent overlay has been identified by Zacharias Vasilakis along a Roman aqueduct supply, most likely designed for private use, to the east of Lebena on the south coast of Crete (I am very grateful to Zacharias Vasilakis for sharing his knowledge of the more extensive water supply systems he has identified in the immediate hinterlands of the sanctuary site).

[4] A spring channel aligned on a north–south axis was reported by Jill Carrington Smith (1 November 1979) in the nearby vineyard of Andreas Kokkinos (KKA 79, Knossos Logbook 106). In 1979 Jill Carrington Smith described a channel covered with slab stones but ruled out a Roman date (KKA 79, Knossos Logbook 106; Sweetman and Grigoropoulos 2010, 375–6), but it is at least possible that this spring source was channelled into the nineteenth-century aqueduct (I thank Todd Whitelaw for reference to the report).

Fig. 3. Detail of *opus signinum* lining Roman channel at the base of the nineteenth-century wall, upper north-west side of Spilia Spur (east of the Katsambas River).

the robustness of the channel's *opus signinum* and the friability of the Roman mortared wall that originally supported it.[5]

Characteristic nineteenth-century aqueduct wall facing along the aqueduct

It was not only the *opus signinum* seam which aided our distinction between the Roman system and the nineteenth-century aqueduct wall built over it; we also recognised a consistent style of wall facing used in the nineteenth-century aqueduct elevations. This later wall facing consisted of roughly cut larger stones, set in mortar, surrounded by smaller chinking stones (Fig. 4).

We first documented this distinctive nineteenth-century facing at the Fundana spring, in the wall abutted by the cement steps leading down to the chapel of Agios Nikolaos. The facing was consistently used along the aqueduct's elevations between Fundana and Caronissi but is perhaps best displayed in the particularly elevated aqueduct wall immediately west of the two-tiered nineteenth-century inverted siphon bridge at Spilia (Fig. 4).[6] The continuous length and elevation of the nineteenth-century wall here (rising to a height of 4.7 m at the edge of the ravine) necessitated some sort of throughway, and it is pierced by a curved arched doorway, measuring 1.3 m high by 0.6 m wide, with a wall width of 2.90 m (Fig. 5, the doorway is marked by the arrow).

The architectural sequencing agrees with references to an Ottoman-Egyptian overlay of the Roman aqueduct observed by Giuseppe Gerola at the start of the twentieth century when he

[5] A similar phenomenon occurred along a section of the Degirmendere aqueduct of Ephesus where only a bedding of sinter survives, below which the wall has completely disappeared (Wiplinger 2019, 241, pl. 214).

[6] The same type of stonework can be seen in numerous nineteenth-century mills and *kouledes* (forts) on Crete, for example, in the koules at Spaniakos, on the Askyfou Plateau, at Potami (above the Amari Dam) and at Anopolis. The koules at Loutro is also built in this style but it reuses materials from the ancient site, with sherds and brick incorporated as chinking material.

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

Fig. 4. Detail of nineteenth-century wall facing (south face), west of Spilia Bridge.

claimed that the later system (Gerola's *opera turca*) followed a Roman blueprint (Gerola 1932–40, 24; Spanakis 1981, 91–2). It also complements Strataridaki, Chalkiadakis and Gigourtakis' (2009, 2, 4 nn. 29–30, pls 8–9) interpretation of pitched roof slabs immediately inside the Skalani tunnel entrance as Ottoman-Egyptian work.[7]

Locating the source

In 1981, Hood and Smyth claimed that the source of the Roman aqueduct of Knossos had 'not yet been identified' (p. 23). Gerola (1932–40, 24), however, reported that the Roman aqueduct of Knossos tapped the spring at 'Fundána', as subsequently reiterated by Roberts (1979, 239) and Spanakis (1981, 24, 92). More recently, the Fundana spring was re-identified by Strataridaki, Chalkiadakis and Gigourtakis (2009, 1) just north of Kounavi village.

In terms of gravity-flow conduction towards the Roman city of Knossos, the topography is most suitable from the springs along the northernmost foothills of Juktas, something Evans

[7] Pitched roofing is not datable per se, and it was used in the aqueduct tunnel at Tralleis (Baykan and Tanriöver 2006, 136, fig. 4*b*), where it acted as a preventative measure against collapse in vulnerable sections.

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

Fig. 5. Elevated nineteenth-century wall, west of Spilia Bridge, doorway marked by arrow.

(1903–4, 52–3) was aware of at the start of the twentieth century. The natural valleys descending northward from these foothills facilitated gravity-flow conduction towards the Roman city, where, despite incorporating an acropolis rising to over *c.* 170 m, with considerable spreads of Roman material extending to its summit, most identified domestic architecture (to date) occurs below *c.* 115 m amsl.

When on-site springs could no longer meet the growing urban demand of Romanising communities, water had to be brought into settlements and cities at an adequate height to serve specific amenities (notably baths and public fountains) (Giorgi 2010, 420). Even when an abundant, but lower, spring existed closer to hand, a source higher in the hills was often tapped by Roman aqueduct surveyors, as sufficient spring altitude underpinned optimal gravity-flow conduction to the destination site and its amenities. In his report of 1629, Morosini emphasises that it was not only the abundance of the springs at Karydaki, but their considerable height above the city (120 *passa geometrici*[8] higher than it) that made them the most suitable source for the aqueduct of Candia (Iraklio) (Moresini, *Relazione* n. 12, in Spanakis 1950, 28).

At Nicomedia, Pliny recommended an elevated arcade for the aqueduct's approach to the city so that its service might not be restricted to the lower zones (Pliny, *Letters* 10.37). That is not to say that lower springs were ignored by locals, and they continued to be used (alongside wells and rainwater cisterns), albeit often for different purposes.[9] At Gortyna, Giorgi (2016, 37–9) suggested that prior to the construction of the large public thermae, on-site springs, rainwater harvesting, and the river itself may have sufficed for the earlier settlement. At Gortyna, the existence of the Roman civic aqueduct is assumed in the first century AD based on the presence of two large bathhouses (the baths in the so-called Praetorium and the Megali Porta baths),

[8] The Italian passo equalled 1.74 m (Steriotou 1992, 271, 273).

[9] Giorgi 2016, 61 n. 178; 2010, 420–1. For the continued use of rainwater cisterns in Cyrene, see Abdrbba 2019, 102–4.

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although the relatively more secure second-century AD date for the aqueduct was established through direct architectural comparison with the Megali Porta baths (Giorgi 2016, 42, 61).

WALKING ROUTE 1 (WR1)

The free-flow bridge below Agios Sozontas (WR1)

Just north of the Fundana springs, the first newly documented aqueduct bridge along the trajectory is nestled in an inlet far below the church of Agios Sozontas where the 1.4 m-wide bridge deck rests at a height of *c.* 171 m amsl (Figs 6–7). While the bridge is marked on the ΓΥΣ map no. 9529/4, it has never been documented archaeologically as part of the aqueduct system. The bridge consists of a single central arch, 3.8 m wide by 5 m high, defined by finely cut voussoirs. The bridge deck containing the water channel sits 6 m above the riverbed. A rock-cut settling tank facilitated the aqueduct's abrupt angle to the north, suggesting that the aqueduct bridge was originally designed as a free-flow system (Fig. 7). It is probable that this small tank had some form of sluice gate for regulations and to allow repair to the bridge channel (see Chanson 2002, 46–8).

While the bridge was very overgrown in 2019, protruding ledges were detected at the base of nineteenth-century walling leading up to, and away from, the bridge. *Opus signinum* lined the ledge protruding from the wall immediately north of the bridge (Figs 8 and 9).

A missing bridge at Skalani (WR1)

On its run up to the tunnel entrance at Skalani, the aqueduct wall disappeared at a direct distance of 320 m south-east of the tunnel entrance (see Fig. 6). This gap presents an unusual hiatus, in that it is the largest gap between documented remains along WR1. On approaching the tunnel, our last sighting of the aqueduct wall (both Roman and nineteenth century) sits at a height of 169.9 m amsl, while the tunnel entrance rests at an elevation of 168.5 m amsl. When we ran a line from our last sighting of the aqueduct wall to the tunnel entrance, the ground dropped by *c.* 7.5 m (i.e. from 169.9 to 162.4 m) below this projected line towards a rivulet running north-east towards Agios Minas, making this the probable location of an elevated structure (Fig. 6). The hiatus in our mapped aqueduct trajectory, together with the drop in ground level below the aqueduct's necessary height here, makes this the most suitable location for an aqueduct bridge, which was blown up near Skalani in the 1897 Revolution, as we know from a letter sent in April that year from British Colonel Sir Herbert Chermside to Antonios Trifopoulos (IAA no. 196, cited in Strataridaki, Chalkiadakis and Gigourtakis 2009, 5, n. 39).

The Roman aqueduct tunnel

Spanakis (1981, 24, 92) reported that a tunnel at Skalani extended for over 1 km. In 2009, Strataridaki's team relocated the entrance of the Roman aqueduct tunnel, just south of Skalani (Strataridaki, Chalkiadakis and Gigourtakis 2009, 2, 4, nn. 29–30, pls 8–9). The interior of the tunnel, measuring 1.7 m–2 m high by 0.75 m wide, is brick lined and vaulted. The brick is 5 cm thick (vertically), with horizontal lengths of 30 cm. The mortar joint is 2 cm thick. About 40–50 cm above the ground, a horizontal seam of sinter seems to define the channel; 85 cm above this, another ledge, 7 cm wide, marks the spring of the vault, which rises another 40 cm. The brickwork of the introdos of the barrel vault alternates along its length: radial brick crowned with a central seam along the apex is visible just beyond the entrance, which gives way to vertically laid brickwork springing from four radial brick courses above the spring of the arch. The brickwork is comparable to that of the service corridors of Bath A in Argos, which is viewed as Hadrianic.[10]

[10] Vitti 2016, 109 n. 42, 113, fig. 3:30. A Hadrianic date accords with past chronologies put forward for the aqueduct: in 1979, Roberts dated the construction of the Knossos aqueduct to sometime before AD 138 and

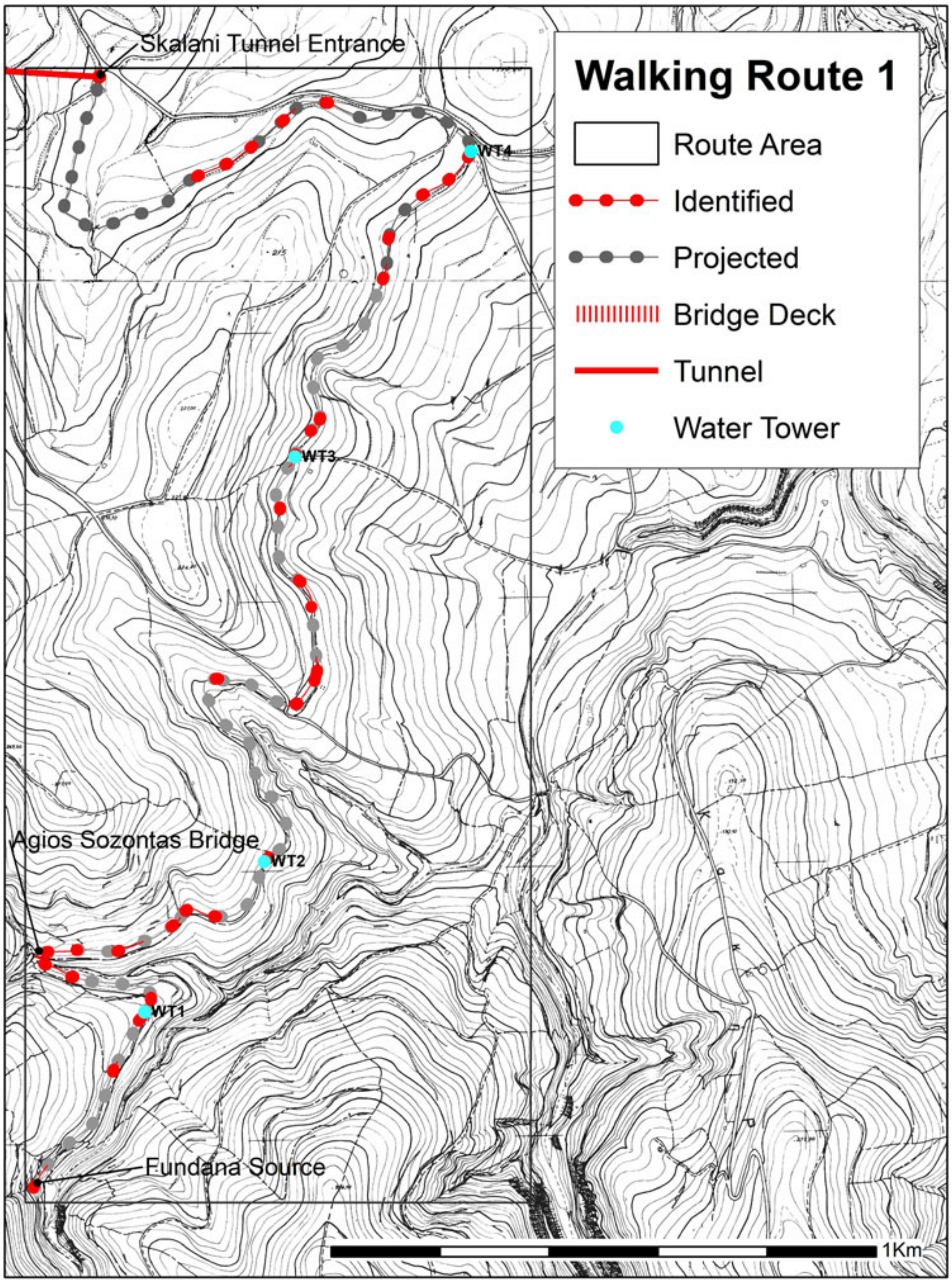

Fig. 6. Walking Route 1 Fundana to Skalani.

The tunnel runs on a roughly west–east 275° bearing for over 1 km and functioned as a gravity-flow water conveyance system (Fig. 10). The terrain only drops to an elevation below that of the tunnel entrance (i.e. 168.5 m amsl) in this direction in the Ampela area, where the tunnel exit was discovered between the Knossos–Charakas road and a small tributary stream. From its entry

perhaps continuing in use until the early 5th century AD, albeit without explaining his reasoning (Roberts 1979, 239 n. 39; see also Hood and Smyth 1981, 23). Strataridaki, Chalkiadakis and Gigourtakis (2009, 1 n. 5) proposed a 2nd-century AD construction date for the Skalani–Ampela tunnel, on the basis of similar 'dimensions and typological characteristics' to tunnels along the aqueducts of Roman Lugdunum (Lyon) and Colonia Claudia Ara Agrippinensium (Cologne) (p. 3).

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

Fig. 7. Rock-cut tank at south end (i.e. the start) of the Agios Sozontas Bridge (with metal pipe embedded in bridging channel).

point of 168.5 m amsl, the tunnel burrows through a hill rising to 244.6 m over its trajectory, effectively traveling *c.* 75 m below the ground surface at its mid-point. In laying out the tunnel, the surveyors perhaps strategically avoided more extensive spreads of elevated terrain immediately north and north-west of the tunnel entrance. The tunnel's final axis and trajectory resulted from an appraisal of the shortest underground trajectory possible for gravity flow in the direction of Roman Knossos. Roman engineers clearly deemed the tunnelling project at Skalani–Ampela a reasonable investment of both time and labour to secure the civic water supply of Knossos; the main benefit driving such a challenging boring project was access to the most abundant spring in the region, that at Fundana.

The tunnel is impressively straight for nearly half its length, at which point some angling is apparent.[11] The tunnel has at least six shafts (Stelios Manolioudis and Manolis Afrathianakis pers. comm.), the first of which is encountered 135 m from the entrance. At this juncture, the passage widens to form a circular ground plan, with a diameter of 1.20 m (reflecting the size of the vertical shaft) (Fig. 10). The area just below this, and every subsequent, shaft is revetted with stonework. While Hero of Alexandria had already outlined the theorem and methodology for boring through a mountain from two given points in the first century AD (Hero *Dioptra* 15; Lewis 2001, 273–4), Roman tunnelling projects could still go wrong.[12] An inscription discovered at Lambaesis (modern Tazoult in Algeria) informs the reader that a second-century AD tunnelling project along the Saldae aqueduct (referenced above) had gone awry, to the point of near abandonment, when it was discovered that the excavation work conducted simultaneously

[11] This angling may represent the junction where two teams met, but tunnels often incorporated angles, which may constitute deliberate measures to avoid impenetrable geological obstructions (Euthanasios Chiotis pers. comm.). The surveyor in Hero of Alexandria's account reports that when an obstacle is encountered along the planned trajectory, such as an impenetrable mass, soft friable rock or a potential pollutant in the geological strata, the tunnel's course had to be adjusted (*Dioptra* 6.120–4).

[12] Themos (1996–7, 402–3) suggested that an abrupt turn midway along the Gythio aqueduct tunnel was a miscalculation.

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

Fig. 8. Nineteenth-century aqueduct wall along north side of bridged inlet, arrows mark protruding ledge of the Roman aqueduct (photographer facing west).

from both ends of a mountain was longer than the width of that mountain (Cuomo 2011, 145; *CIL* VIII 2728). The El Habel tunnel along the Saldae aqueduct burrows 86 m below a ridge to the west of Ifran, presenting a challenging depth for sinking shafts (although shafts along qanats have been sunk to over three times this depth).[13]

The water conveyance tunnel at Skalani–Ampela is nearly twice as long as the notorious Saldae tunnel (see Table 1). The water tunnel serving Roman Knossos burrowed far deeper and for far longer than any other Roman water tunnels on Crete (see Table 1 for comparisons). It is five times longer than the Chersonisos tunnel, which only travels *c.* 5 m below ground surface, although Oikonomakis (1986, 52, 56, 61) was unable to examine its interior as it was half-filled with earth. It is also 26 times longer than the Eleutherna tunnel, which travels at a depth of *c.* 10 m below ground surface, emerging on an elevated eastern scarp on the city's acropolis (Sarris et al. 2015, 695). Water tunnels in Crete also differ in form and finish: at Eleutherna, the unlined tunnel walls wind back into the bedrock, as opposed to the linear trajectory of the brick-faced interior of the Skalani–Ampela tunnel. The tunnels curving into the bedrock at Polyrrhenia have been dated to the Classical or Hellenistic periods.[14]

[13] Laporte 1996, 744. Hero (*Dioptra* 20) advised the construction of a shaft for an already existing tunnel, should that tunnel need repair (see Lewis 2001, 278–9).

[14] Voudouris et al. 2013, 1332; Markoulaki and Christodoulakos 2018, 99. The full extent of the water tunnels at Polyrhennia is unknown. In the 1830s, villagers informed Pashley (1837, II.48) that the tunnels travelled for 'one hour underground', and even this was increased to a distance of two hours by the time Thenon visited in the 1860s (Thenon 1867, 421), with Stillman (1868, 331) claiming that the other side of the hill could be reached through the tunnels.

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

Fig. 9. *Opus signinum* along the protruding ledge of the Roman aqueduct along base of nineteenth-century wall, north of bridged inlet.

In terms of field study, pinpointing the tunnel entrance at Skalani established a fixed point which could then be used as a double-check for our plotted trajectory up to this point (Fig. 1). The entrance of the water tunnel lies at an altitude of 168.5 m amsl, and in order for the system to function, water had to be channelled along a gentle gradient from a spring to that location. The only spring situated at a sufficient height and suitable situation to reach the tunnel entrance is that of Fundana (at an altitude of 175 m amsl). A simple exercise of projecting a line of gentle gradient from the tunnel entrance back to the spring allowed us to map a fairly accurate aqueduct trajectory running along a slope of 0.129 per cent or 0.07° (with a rise 6.5 m and a run of 5025 m) (covering WR1; Fig. 6). Along this 5.02 km stretch, the average gradient is 1/773, comparable to the average fall along the Gier aqueduct feeding Lugdunum (modern Lyon) in Gaul at 1/725, and that along a section of the Eifel aqueduct approaching the Swist Fault system (Hoffman et al. 2019, 2354, fig. 3). The altitude and position of the Skalani–Ampela tunnel entrance, the Roman construction date of the tunnel and its reuse in the nineteenth century demonstrate (without the need for any further fieldwork) that the spring at Fundana was tapped by both systems, almost two millennia apart.

WALKING ROUTE 2 (WR2)

We plotted a 2.19 km stretch of aqueduct running from below the tunnel exit at Ampela to the upper reaches of the Spilia Spur (WR2, on Fig. 1). This section of the aqueduct had not been documented before our fieldwork (see Strataridaki, Chalkiadakis and Gigourtakis 2009, 3).

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

Fig. 10. Interior of the Skalani–Ampela tunnel, photographer facing west.

Ampela Bridge 1 (WR2)

Below the tunnel exit (at *c.* 163–4 m amsl), the nineteenth-century aqueduct wall leads northwards towards the first of two bridges. About 140 m north of the tunnel exit, the aqueduct crosses a south–north flowing rivulet on a single arched free-flow bridge (Fig. 11). Prior to 2019, this aqueduct bridge had not been identified as part of the aqueduct system, although a bridge is marked in this spot on ΓΥΣ map no. 9529/2. The aqueduct wall leading up to the bridge is 1.10 m wide but the bridge deck, resting at 161 m amsl, widens to 2.38 m. The increased thickness of the bridge, and a cross wall rising from the western end of the bridge deck, suggests that the water bridge may also have served as a footbridge.

Although the bridge elevations display characteristic nineteenth-century facing, the rivulet is heavily silted up and only the upper portion of the bridge is currently visible (Fig. 12). The arch rib is defined by finely dressed sandstone voussoirs, measuring, on average, 25 cm by 25 cm by 50–60 cm long, with smooth fitted radial joints, finely convex soffits and roughly shaped upper surfaces. The voussoirs of both Ampela bridges are similar in stone type, dimension, fitting and finish.

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

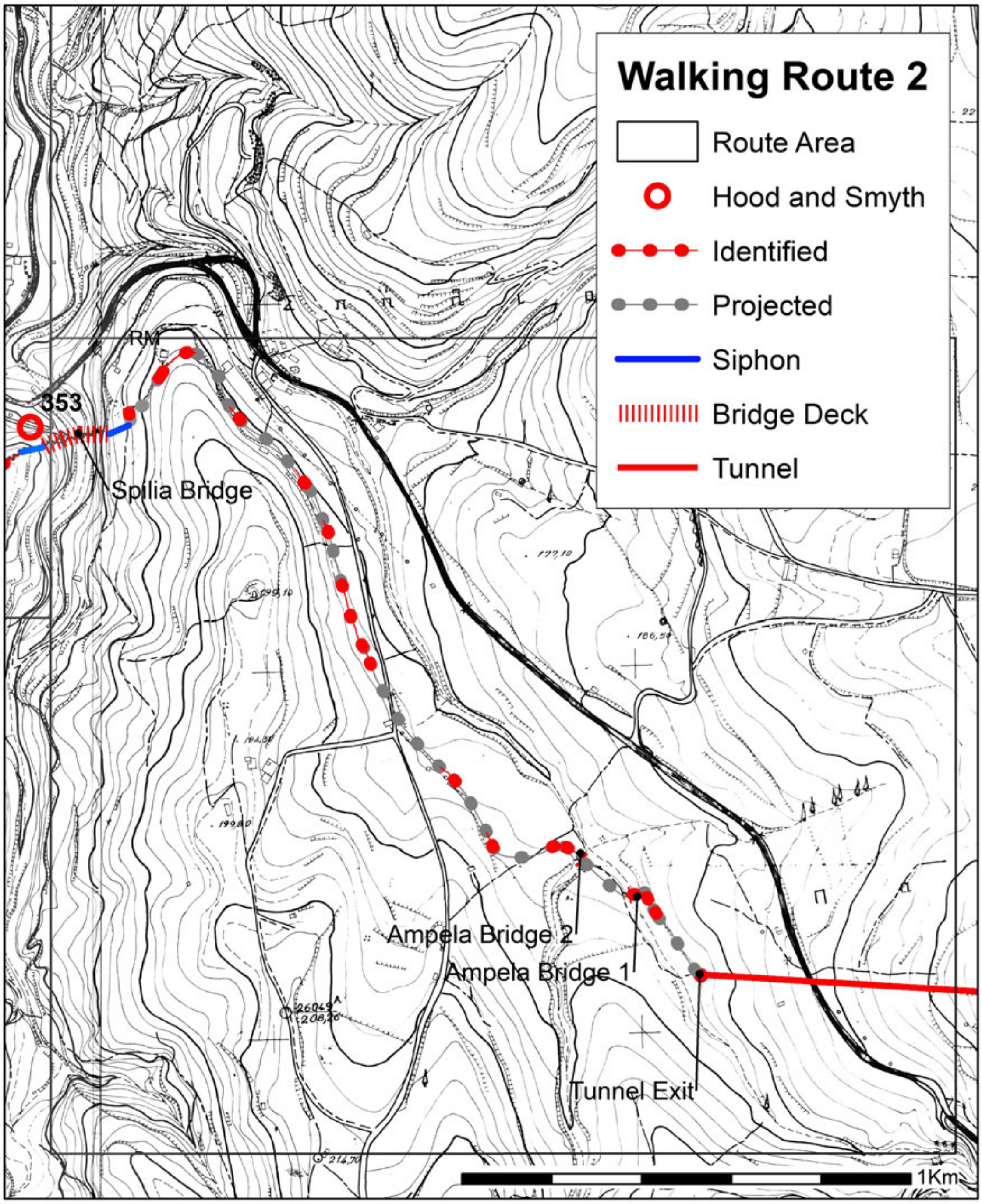

Fig. 11. Walking Route 2 Ampela to Spilia.

Ampela Bridge 2 (WR2)

Moving north along the west side of the rivulet, another aqueduct bridge was recorded (at the first modern house along WR2), where the ground dips down to meet a tributary stream (Fig. 11). Again here, the bridge deck is a wider structure than the aqueduct wall leading up to, and effectively abutting, it. The aqueduct bridge had not been previously documented archaeologically as part of the water supply system, but the bridge is marked on ΓΥΣ map no. 9529/2. This aqueduct bridge (Fig. 13), with its finely dressed sandstone voussoirs defining a single arch spanning 2 m, is very similar to Ampela Bridge 1.

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

Fig. 12. Ampela Bridge 1, south face. Note crack and slipped voussoirs along right side.

The axis of the bridge follows a bearing of 290° south-east–north-west. Immediately north of the bridge, the aqueduct wall changes direction, angling 20° to follow a bearing of 310°, while 14.1 m further along its course, the wall angles to the north-west following a bearing of 270°. The join at the first angle features a misalignment in the lower tier of the wall, but this is rectified in the upper tier. This two-tiered joinery suggests a phasing in the construction of the height of the wall while the misalignment at the lower level at the edge of the bridge also suggests that two teams operated at ground level: one responsible for building the arch of the bridge, perhaps a specialist crew, and another charged with general wall construction.[15] The wall elevation at Ampela 2, rising to almost 3 m, displays characteristic nineteenth-century facing; however, it is tempting to see an earlier phase to this bridge's architectural foundation, but both bridges are heavily silted up.[16]

The Roman aqueduct on either side of the Katsambas River at Spilia

The next waterway to be bridged – the Katsambas River – presented a more serious obstacle for the aqueducts' progression. At either side of the ravine at Spilia, stretches of the Roman channel lined with *opus signinum* were identified (Figs 3 and 14 on the east, and Figs 15–16 on the west). Remains of the Roman aqueduct on the east and west sides of the river are interrupted by a dramatic

15 For teams at work on aqueduct projects, see Jansen 2019.

16 Similar bridge overlays were reported in 1937 by Ralegh Radford, who noted that 'the remains of a Roman bridge [KS 81?] partly overlaid by others of medieval or Turkish date exist on either side of the Kairatos [Katsambas], a quarter of a mile below the village of Makry Toikhos' (Radford 1937, 6, no. 9; I thank Todd Whitelaw for this reference).

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

Fig. 13. Ampela Bridge 2, west face.

fall of 24 m (resting at 161 m amsl to the east and 136–7 m amsl on the west side of the river). The *opus signinum* in both sections identifies the two tracts as Roman, despite the dramatic drop separating them.[17]

For the first time along its route from Fundana, the Roman aqueduct wall is free-standing immediately west of the Spilia Bridge (KS 353) and the Roman line is no longer directly overlaid by the nineteenth-century system. The 1.65 m-wide free-standing Roman aqueduct wall survives in its entirety here, demonstrating the degree of destruction caused by direct overlay up to this point (Fig. 16). The two aqueducts diverge here, with the later aqueduct adhering to the higher ground traversing the crest of the hill to the west-south-west and the Roman aqueduct following an east–west running contour below this for a length of 35 m (Fig. 16).[18] The Roman wall supports a 0.40 m-wide channel, which rests on a series of *bipedales*, seen here for the first time along the aqueduct's route.[19] The Roman channel is lined with a 10 cm-thick coating of *opus signinum* incorporating corner bevels.

That Roman walling lined with *opus signinum* runs up to, and away from, this point on either side of the valley suggests that the Roman aqueduct crossed the river in the same location as the

17 Identical *opus signinum* also coats cisterns in the Roman city of Knossos, in Knossos village (formerly Bougada Metochi) and in the Theatral area of the Minoan Palace, while two parallel lines of *opus signinum* adhered to the wall flanking the Royal Road (mentioned below).

18 The Roman aqueduct wall is cut by the later aqueduct at the eastern end of this tract.

19 Admittedly, the sudden presence of *bipedales* in this tract might even point to a second Roman aqueduct descending the contours of the Katsambas and thereby refute any connection with the channel from Fundana, but, at this point, we do not have conclusive evidence for a second Roman aqueduct supplying Knossos from Karydaki (see Kelly 2022). Further east, we also identified a rock-cut aqueduct channel in the Krateros Gorge near the church of Agios Nikolaos.

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

Fig. 14. Detail of *opus signinum* lining Roman channel at the base of the nineteenth-century wall, upper north-west side of Spilia Spur (east of the Spilia Bridge/Katsambas River).

nineteenth-century Spilia bridge.[20] If this is the case, how the Roman system facilitated such a dramatic drop remains unknown at this point. It is possible that the Roman aqueduct did not use an inverted siphon to cross the river; instead, we might envisage a chute or cascade facilitating a lowering of the water level on the east side of the river, from where the water could be channelled across the river on a free flow bridge. Sizable chunks of mortared Roman masonry (incorporating wall elevations and a partial floor foundation) were identified on the north-west slope of the Spilia Spur about 3 m above the modern roadway (marked RM on Fig. 11). This structure could theoretically have served as a water dropping device or chute; various structural devices, including chutes, cascades, and dropshafts, facilitated drops in height along free-flow channels, as outlined by Chanson (2000; 2002; see also Lewis 1999, 153). The Brévenne aqueduct at Lyon, for example, has a longitudinal gradient of about 0.4 per cent to 1.25 per cent, but the gradient is made up of gently flowing tracts broken up by a series of steep chutes (Chanson 2000, 67, table 1, fig. 19; 2002, 44).

[20] Ralegh Radford, in his 1937 report, noted that 'the acqueduct [*sic*] supplying Candia is in its present form the result of a repair attributed to Achmet Ali. There is also Venetian work. Trace of a Roman acqueduct [*sic*] on the same line can be seen, where it crosses the Kairatos, and also at the base of a small gorge where it diverges from the modern line' (Radford 1937, 6, no. 10; I thank Todd Whitelaw for this reference).

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

Fig. 15. Roman aqueduct wall and channel (foreground), nineteenth-century walling in background (north face), west of Spilia Bridge/Katsambas River.

The nineteenth-century bridge at Spilia

The inverted siphon system at Spilia, replete with its two-tiered venter bridge (Fig. 17), was constructed in 1838 (Bowring 1840, 162), reportedly under the supervision of local foreman Theodoraki Georgiadis or Koutagiotis from the village of Agios Thomas.[21] While the inverted siphon at Spilia constitutes a nineteenth-century construction, pressurised systems, including inverted siphon technology, were widely applied along Roman aqueducts.[22]

The inverted siphon at Spilia is a massive structure; if we include the adjacent descending and ascending wings, the bridging structure is 186.6 m long. A gallery quarry has been identified along the west side of the Spilia Spur, with further traces of quarrying along scarps to the south of the bridge on both sides of the valley (Todd Whitelaw pers. comm.), although whether these were opened for the bridge's construction is unclear. The start of the inverted siphon structure at Spilia is now marked by a cemented header tank, from which the outflow pipe rests at an elevation of 147.5 m amsl. But it is important to remember that the water (in both systems) began its descent from higher up on the Spilia Spur at an altitude of 161 m amsl, representing a drop of *c.* 13 m before reaching the nineteenth-century inverted siphon structure. From the tank, pipes descended to the bridge deck, which sits at a height of 130.9 m amsl, constituting another drop of 16.6 m. The drop from the aqueduct rounding the summit of Spilia to the deck of the venter bridge is *c.* 30 m.

[21] Spanakis 1981, 92; Strataridaki, Chalkiadakis and Gigourtakis 2009, 4; Chalkiadakis 2012, 460. Dawkins referred to the Spilia Bridge as *Kamara tou Khatzidaki* (Notebook 15 August 1917, for which see Mackridge 2020, 242), with no explanation.

[22] For the operation of an inverted siphon, see Hodge 1983.

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Fig. 16. Free-standing Roman aqueduct wall, west of Spilia Bridge/Katsambas River.

In an inverted siphon system, free-flow can only resume at some point below the height recorded at the start of the inverted siphon, a point usually marked by a header tank, but, at Spilia, the absence of a receiving tank on the opposite western brink of the ravine suggests that the full extent of the inverted siphon lies further west. The height of the immediate ascent on the far side of the river only reaches *c.* 142 m amsl, and the channel elevation continues to climb, albeit more gently until it reaches a now-ruined mansion (marked on ΓΥΣ map 9529/2 280 m west of the header tank) where the channel sits at 144 m amsl. That inverted siphons could transport water for considerable distances can be seen elsewhere on Crete, in the inverted siphon supplying Roman Lyttos which extended for about a kilometre, initially following a 310° bearing north-north-west, but incorporating a 40° angle west-north-west about 500 m along its length, before the aqueduct turns northward to reach the city (Kelly 2018, 164). Burdy (2001, 40, table 1) recorded lengths of inverted siphons along the Gier aqueduct of Lyon extending to 575 m (Trion), 700 m (Durèze), 1210 m (le Garon) and 2660 m (Yzeron) with venter bridge lengths of 136 m (Durèze), 210 m (Garon) and 270 m (Yzeron) (see also Kessener 2022, table 4).

At Spilia, pressure in the nineteenth-century inverted siphon was relieved by a two-storey venter bridge. The deck, containing the water conduit (fitted with pipes), crosses the river at a height of 130.9 m–129.9 m amsl (Fig. 17). The lower storey of the venter bridge consists of a single curved arch spanning the riverbed, with its apex directly above the riverbed below (see also British School at Athens Society for the Promotion of Hellenic Studies Image Collection 01/3913.7601). The second storey stands on a 6.3 m-wide foundation and accommodates four pointed arches: a large arch (16.6 m wide by 4 m deep) positioned directly over the main curved arch of the lower storey spanning the river, a roadway arch and two smaller relief window arches. The first storey rises to the height of the modern road; this roadway passes through a pointed arch (6.8 m wide and 4 m deep) in the bridge's second storey. The potential antiquity of this routeway along the river was noted by Evans (1928, 62). The arches at Spilia are all architecturally functional, serving to relieve weight, while also allowing the river and road to pass through the structure. The double window arches in the upper storey, while relieving weight at a key point, are also strategically placed to break up the otherwise imposing façade between the two larger arches of the second storey, where they perhaps guard against wind and earthquake damage within such a narrow gorge.[23]

WALKING ROUTE 3 (WR3)

On crossing the Katsambas River, the Venetian aqueduct descending from Karydaki joins, or shadows, the Roman system; as reported by Gerola (1932–40, 24) who first noted the convergence of the aqueduct systems between the bridges of Silamos and Caronissi. In 2019, this convergence was pinpointed in the field. The Venetian aqueduct descends along the Katsambas River from which it departs just south of the village of Agia Irini. Its route is clearly marked by a zig-zag line (on maps ΓΥΣ 9529/3 and ΓΥΣ 9529/1) running from the Silamos Bridge northwards, veering north-west just south of Agia Irini village (Kelly 2022, 119, fig. 2, 149). On ΓΥΣ 9529/1, the zig-zag line marking the Venetian aqueduct's descent from the Silamos Bridge continues as a dotted-dash line after crossing the road leading eastward down to the village of Agia Irini. At this point, the line joins the contour marked 160 m on ΓΥΣ 9529/1 (although closer to 150 m in the field); this trajectory is delineated in the field by a wall supporting a footpath. A section of the wall's façade was recently coated with mortar obscuring the original stonework. A long stretch of this wall is visible further north, directly west of KS 351, where it again supports the footpath (KS 351 is marked on Fig. 18). This wall and the footpath itself constitute the Venetian aqueduct which runs higher than, and parallel to, Roman aqueduct tracts KS 352 and KS 351 (marked on Fig. 18).

The east slopes of the Upper Gypsadhes (WR3)

Where a small depression interrupts the aqueduct's northerly trajectory, substantial tracts of mortared masonry follow a north-west course. Two substantial segments of mortared walling loop around this shallow depression. A 16 m length of mortared masonry, possibly abutting a scarp, is visible running behind a chicken coop at the back of a modern house. The wall's core is exposed, with little facing remaining. To its immediate north-west, a substantial freestanding mortared wall extending for 3.75 m may be a continuation of the wall running behind the property (Fig. 19). This short wall segment may have collapsed from the scarp as it sits at a slight tilt. If so, the entire length of this surviving stretch of walling would measure 25.6 m. This section of mortared walling has a façade of neatly cut blocks, *c.* 15 cm by 30 cm, laid in layers of roughly equal height. Another substantial section of mortared masonry lies within a fenced garden immediately to the west, but we could not gain access to it in 2019.

This masonry most likely represents Hood and Smyth's KS 350 (marked on Fig. 18), which they described as 'stretches of Roman aqueduct … comparatively well preserved where it was

[23] Small relief arches, or window arches, are common in Ottoman bridges, as seen in the upper storeys of the aqueduct supplying the Simonos Petra Monastery on Athos. Relief arches are often located in the spandrels of bridges, as seen in the nineteenth-century Dunavat Bridge or Manalat Bridge in Albania.

Fig. 17. Venter bridge at Spilia, south façade (Fondo Giuseppe Gerola, Copyright Istituto Veneto di Scienze, Lettere ed Arti, all rights reserved).

transported across a gully' (KS 350). It is, however, unlikely, that the walling identified in 2019 represents Roman construction; its height above sea level and its neat blockwork point to a Venetian date. Roman walling studied along other sections of the aqueduct in 2019, where it did survive, was particularly friable and prone to collapse. Often only the *opus signinum* of the channel was found *in situ*, whereas the blockwork of this wall section has a strong bonding mortar. It is likely that Hood and Smyth's KS 350 represents the blockwork of the Venetian aqueduct. The Roman trajectory must be lower lying and potentially covered by soil subsidence; KS 351, 352, 347, 346 and 318 were all found below ground surface.

To the north, another sizeable free-standing fragment of mortared masonry nestled, although possibly on its side, at the foot of the steep bank below the wall supporting the footpath, presumably from where it rolled. The road sits at roughly 150 m amsl and the base of the escarpment below it sits at 131 m amsl. Further on, another square of mortared masonry, with a possible channel cut, sits at the base of the slope descending from the wall supporting the path. These sections of walling might represent Hood and Smyth's KS 349 (marked on Fig. 18), which they described as a 'stretch of Roman aqueduct with part of the water channel intact, visible for some 10 metres in the side of a steep bank below the path … about 100 metres north of 350. The western edge of the channel has survived in places with a bevel some 0.05 metres wide at the bottom.'

The Venetian and Ottoman-Egyptian upper terrace

The Ottoman-Egyptian and Venetian aqueduct walls form parallel terraces along the eastern contours of the Upper Gypsadhes (marked on Fig. 18). The upper terrace runs from the gully (mentioned above) for 311 m and serves as a footpath, or *kalderimi*. At the gully, the upper terrace rises to 151 m amsl (at its south end) gently descending to 147 m amsl at its northern end.

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

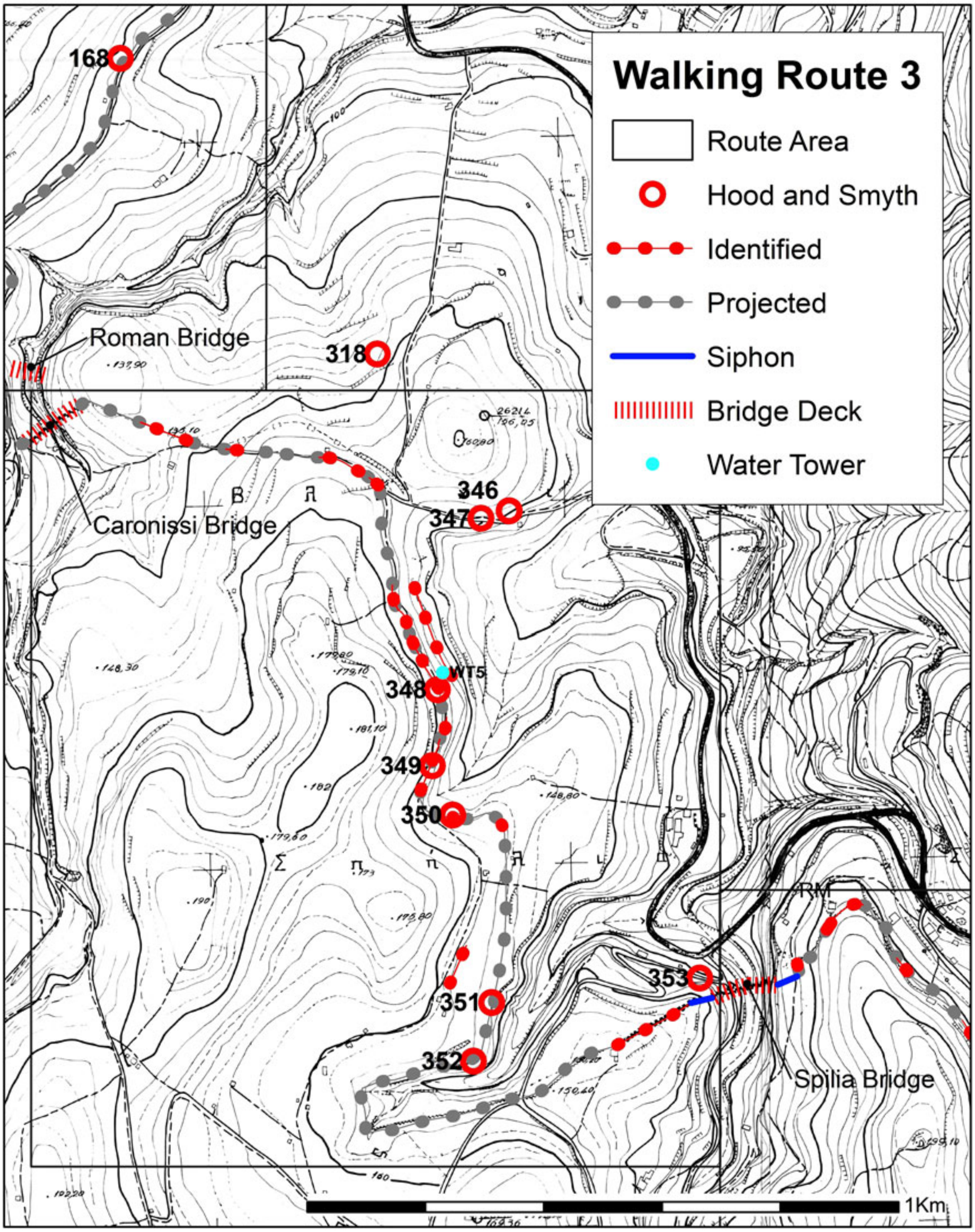

Fig. 18. Walking Route 3 Spilia to Caronissi.

A particularly substantial section of masonry supports the upper terrace for 19 m, although it gently diverges from the terrace for up to 4 m (Fig. 20). This tract of masonry is located at an angle north-north-west midway along the upper terrace. This supporting wall exhibits substantial blockwork and must represent Hood and Smyth's KS 348 (marked on Fig. 18), which they described as a 'stretch of Roman aqueduct … exposed as a terrace wall some 20 metres long and standing to a maximum height of about 3 metres just below the path. Other shorter stretches are visible some 35 metres to the north and south' (KS 348).

Fig. 19. Mortared masonry blockwork, possibly KS 350, photographer facing west.

A seam of a substantial foundation wall extends northward for at least another 14 m from KS 348 towards a culvert at the base of the wall. Another 2.66 m-long segment of mortared masonry is evident at the base of this upper terrace wall, 8.5 m further north. These remains of substantial walling supporting the upper terrace probably constitute the Venetian aqueduct, which was subsequently overlaid by the Ottoman-Egyptian aqueduct along this contour.

Between these earlier, and possibly Venetian, elevations, the upper wall supporting the terrace is faced with nineteenth-century stonework, consisting of roughly cut larger stones surrounded by smaller chinking stones laid in mortar. Further north, two phases form clear architectural horizons in the wall elevation. It seems likely that this narrow ledge or terrace originally held a water channel, probably that of the Ottoman-Egyptian aqueduct which was built directly over the wall of the Venetian aqueduct. Along the northernmost section of this narrow terrace (and close to KS 331), nineteenth-century walling is also visible above the pathway along its western edge where it presumably protected the channel.

The lower Gypsadhes loop

In 2019, we documented channels and walling turning to the west/left at the road junction, constituting a clear break from the trajectory recorded in the 1981 Knossos Survey in which the Roman aqueduct circumnavigates the Lower Gypsadhes spur (KS 346–7 and 318; marked on Fig. 18). In November 2019, we were unable to find these three tracts recorded in the Knossos Survey, as all three were originally discovered in deep cuttings or excavated trenches: KS 347 was unearthed in a trench dug for a water pipe in the 1970s;[24] KS 346 was visible in an emplacement dug in the Second World

[24] '347. Section of ROMAN AQUEDUCT (cf. 318, 346, 348-53) cutting across the line of the trench for the new water pipe to Fortetsa, studied by Hood and Smyth in 1976. E 8' (KS 347).

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Fig. 20. Wall of mortared blockwork, possibly KS 348, photographer facing west.

War;[25] while, in 1968, the cover slabs of KS 318 were recorded as *c.* 1.10 m below ground surface.[26] The fact that all three tracts lay below ground surface impeded their identification in 2019. The existence of these tracts, however, confirms that the Roman water supply ran on a lower contour than the Venetian and Ottoman-Egyptian lines along the east foothills of the Gypsadhes.

KS 347 and 346 would be relatively well placed for connectivity with a trajectory running northwards from below KS 350–348. It is also interesting that Hood referred to an early and later Roman system diverting here, the earlier looping the Lower Gypsadhes hill and the later turning west on a more direct approach to Caronissi (see Knossos Logbook 52). The detour around the Lower Gypsadhes (represented by three short tracts recorded in 1981) could be integrated in a wider appreciation of the Roman system.

A lower-lying Roman cistern was also located in the 1970s when it was exposed in a road cutting (KS 319). Hood and Smyth proposed that it was indirectly fed by aqueduct tracts KS 348–53, but this supposition is difficult to substantiate given the cistern's much lower altitude. At any rate, cistern KS 319 was a substantial double cistern, measuring 10.80 m by 5.6 m (Knossos Logbook 41–2).[27]

[25] '346. ROMAN AQUEDUCT continuing the line of 347. visible at the north end of an emplacement dug in the Second World War about 10 metres north of the road. The aqueduct at this point was evidently built in a cutting which ran along the side of a steep bank, as at 352. A section of the channel was exposed in April, 1977, in the steep cutting on the north edge of the road about 40 metres to the west. E 8' (KS 346).

[26] '318. Section of the ROMAN AQUEDUCT (as 346–53), consisting of a large stone-built water channel with bevelled edges (0.41 metres wide and 0.70 metres deep) lined with gritty pink plaster and covered with slabs, examined by M. Popham and R. Howell in 1968 on land of Kostas Karkalouzos about 50 metres west of the road. The tops of the cover slabs were *c.* 1.10 metres below the surface. D 8' (KS 318). For further notes on the channel in this area, see Knossos Logbook 45, letter from Popham, 4 October 1975.

[27] I thank Todd Whitelaw for bringing these logbook entries to my attention.

The approach to Caronissi

In deference to the earlier reports, we must envisage a Roman tract looping the Lower Gypsadhes, but the later systems take a more direct route westward towards Caronissi. Directly north of the parallel terraces, walling was visible in the surface of the dirt road in 2019, near KS 330. A little further on, at the T-junction (just past KS 334), the walling veered west/left where it was visible along the side of the road surface. So instead of circumnavigating the Lower Gypsadhes, we plotted visible architecture turning west along the road surface.

Where the ground dips to the north-west, the walling became elevated along the roadside, incorporating a 60 cm-wide architectural ledge. As the road turns due west, descending to the Caronissi Bridge, a 40 cm-wide channel was evident in the road surface (Fig. 21). Another 40 cm-wide channel with neatly fitted limestone capstones crossed the road before its final free-standing run to the bridge; the careful stonework and neat positioning of these capstones is reminiscent of the stonework in the Venetian Caronissi Bridge (mentioned below), suggesting contemporaneity here. By 2021, the road had been resurfaced covering these particular remains (Amanda Kelly, personal observation).

Fig. 21. Channel in the road surface on descent to the Caronissi Bridge, photographer facing east.

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

The Caronissi Bridge

The three water systems cross the Vlychia tributary on their approach to Knossos on two bridges: the nineteenth-century system reuses the elegant Venetian free-flow Caronissi Bridge while the Roman aqueduct crosses the ravine on a bridge to its north (marked on Fig. 18).

The deck of the Caronissi Bridge sits at an elevation of 130.13–129.5 m amsl, with the riverbed resting *c.* 30 m below. The bridge's stonework is distinctive, consisting of neat series of regularly cut rectangular blocks, 30–80 cm in length, set in linear courses of equal height (rising to just over 20 cm). Diagonal tooling is visible on the face of the stonework, while patches of mortar coating, faintly scored by criss-crosses, are also visible.

A 60° angle to the south-west marks the aqueduct's direct approach towards the river, and from here, it runs for 117 m until it meets the modern roadway on the far side of the river.[28] At the lip of the gorge, some 42 m from the initial angle, the aqueduct incorporates a more subtle 10° angle, which lines up the bridge perpendicularly to the river. This perpendicular arrangement between bridge and river reduces the required building materials and minimises the structural vulnerability of the bridge (Hubert Chanson pers. comm.). Gerola measured the Caronissi Bridge at 54 *passi* long with a single arch rising to 70 *piedi* with a width of 30 *piedi* (Gerola 1932–40, 17, fig. 4, 18, 22, fig. 8 [showing south façade]).

A Venetian inscription, and a lion in relief, decorate the northern façade of this bridge above the apex of the arch. The inscription was published by Gerola, who noted that the text had been erased by the 'Turchi', so that only the first and sixth lines could then be partially detected (1932–40, 378, n. 6). The name Maurocenus Franciscus (Francesco Morosini), the civil governor of Crete in that year, is legible in the first line, and the year 1627 is clear in the sixth and final line (Kelly 2022; Gerola 1932–40, 378, n. 6).

Strataridaki, Chalkiadakis and Gigourtakis, citing Stavrinidis, report that the nineteenth-century trajectory reused the Venetian bridge in the Vlychia area on its course to Iraklio.[29] This reuse is complemented by both the textual erasure but also repair work evident along the deck of the bridge, accommodating the channel, where work in small bonded stones creates a distinctive seam in the masonry. The insertion of small chinking stones around the regular blockwork and, consequently, re-grouting over them may also represent later work.

Roman bridge piers to the north of the Caronissi Bridge

A Roman bridge was recorded in the 1981 Knossos Survey as consisting of 'concrete stumps of supports for [the] Roman aqueduct crossing the Vlikhia stream bed north of the Venetian aqueduct' (KS 160). In 2019, a masonry block, measuring *c.* 4 m wide north–south, 1.5 m high and 1.5 m deep, and consisting of roughly cut mortared stone, projected from the lower western side of the riverbed (Fig. 22; see also Kelly 2004, vol. 1, 100, vol. 2, 32 n. 8.5, vol. 3, pl. 16*a*–*b*). Two other blocks of mortared masonry were plotted higher up on the east (117.22 m amsl) and west (118.3 m amsl, as marked by a square rock-cut cistern) banks of the river (marked on Fig. 23). The Roman mortar in these piers, and throughout the Roman system's walling, is highly friable and prone to disintegration. With only three stumps of masonry surviving, the form and operability of this aqueduct bridge remains unclear; however, the Roman bridge deck may rest at a lower level than its Venetian counterpart, which might explain the adherence of the nineteenth-century system to the Venetian course, once it encountered it along its route.

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[28] Angled approaches to river crossings can be seen along the aqueduct of Thessaloniki at the Hortiatis Bridge (Manoledakis 2018, 53, fig. 1) and along the aqueduct of Safranbolu in Turkey at the Incekaya Bridge (Ertürk, Şeker and Öztürk 2013, 746, fig. 3).

[29] Strataridaki, Chalkiadakis and Gigourtakis 2009, 4 n. 32; Stavrinidis 1969. In 1931, Nikolaos Stavrinidis began translating and publishing the court documents of Iraklio (now kept in the archive of the Vikelaia Municipality Library); he published the material from 1656 to 1909 in five volumes (Bayraktar 2005, 5).

Fig. 22. Roman Bridge north of Caronissi Bridge, masonry pile on low west bank.

WALKING ROUTE 4 (WR 4)

On its final approach to the Roman city, the aqueduct was difficult to detect in 2019, although previously recorded walling was re-identified at a group of rock-cut tombs (KS 168) lining the roadway "της φασκομηλιάς" (marked on Fig. 23). In 2019, only the mortared foundations of a wall were visible in the western road scarp adjacent to these tombs near the ruined church of Agios Kirillos. This was the only walling recorded along this roadway between the bridging of the Vlychia and the Roman cistern in Knossos Village (Bougada Metochi), and even this could not be dated with confidence. A Roman cistern was, however, reported from south of this tomb and compared to cistern KS 319 (KS 168); this could not be identified in either 2019 or 2021. Due to the scarcity of Roman aqueduct remains along the roadway, it is possible that the Roman line ran parallel to, but below (i.e. to the east of), the roadway on its run up to the village.

A Roman cistern in the upper village of Knossos (Bougada Metochi)

In 1981, a Roman cistern, KS 191, was reported in the upper village of Knossos (formerly Bougada Metochi). At that time, the remaining architecture measured 8 m north–south by 1.35 m, and while no corners were mentioned, reports of a bevelled edge indicate the angle along one side of the flooring. Hood and Smyth described KS 191 in the following manner: '[a lining] of cement with red tile chips was about 0.15 metres thick; a later lining of cement with finer red chips about 0.05 metres thick was superimposed on this', where the second coat suggests a prolonged functional life.

This cistern was photographed by the author in 1999 when its floor measured 3.5 m long and 1.3 m wide (Kelly 2004, vol. 2, 33, vol. 3, pl. 17*a*). It was then still lined with thick *opus signinum*

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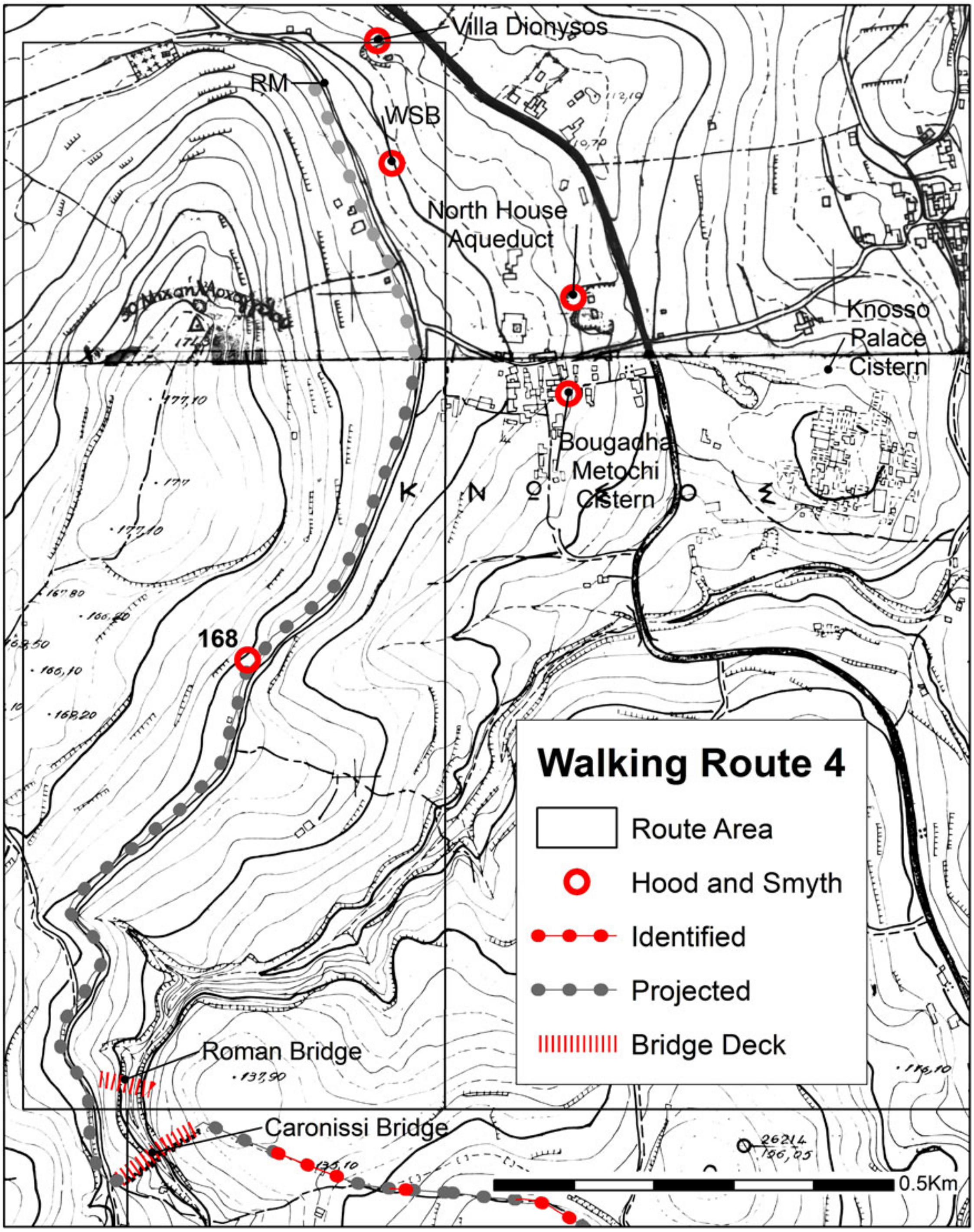

Fig. 23. Walking Route 4 Caronissi to Knossos village (formerly Bougada Metochi).

incorporating a bevel. In 2019, the position of the cistern was relocated, using the background of photographs taken in 1999, but the cistern has since been removed to make way for private parking. The cistern sat at an elevated height of 105.3 m amsl, a suitable level for distribution to the north and east, a distribution also suggested by Hogarth (1899–1900a, 81, pl. xii).

The cistern was not an isolated water facility within the village's footprint and, when Hogarth sank trials in the village (approximately 25) in 1900, he came upon 'considerable remains of

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Table 2. Roman architectural remains identified within the footprint of the modern Knossos village.

Roman sites in Knossos village	Mosaic	Bath	House	Building/ walling/ cement	Cistern/ well	Industrial area	Sculpture	Shrine	Road
KS 181					*				
KS 189				*					
KS 190					*				
KS 191			*		*				
KS 193					*				
KS 194					*				
KS 195	*		*						
KS 197							*	*	
KS 198				*					
KS 199			*						
KS 208									*
KS 210					*				
KS 372					*				
OTE 13–16				*					
DEYAH				*	possible				*
KEB				*		*			
KEV		possible		*					
KKB				*					
KKE	*	*							
KKK					*	possible			
KMV			*						
KNPP				*					
KPK					*	*			
KSV						*			*

houses, water-conduits and cisterns … associated with Graeco-Roman sherds' (Hogarth 1899–1900a, 80–1; also referenced in Hood and Smyth 1981, 32 n. 96, see also KS191). Rethemiotakis and Warren (2014, 3) reported a Roman floor and walls in the Vlachakis Plot in the lower part of the village. Table 2 presents Roman remains identified within the village footprint by the 1981 Knossos Survey and in reports on a series of rescue trenches compiled by Sweetman and Grigoropoulos (2010, 343–5, table 1, fig. 3; see also Fig. 24). Roman tombs KS 168, 169, 170 and 202 may mark the southern extent of this architectural spread. The southern boundary of the Roman city has been well established by surface collections recorded by the Knossos Urban Landscape Project (see Trainor 2019, 2, 4–5; Whitelaw, Bredaki and Vasilakis 2019b, 12–14, figs 14–17).

An aqueduct branch supplying the North House

A Roman aqueduct branch supplied the North House quarter 110 m due north of the cistern in Knossos village (Bougada Metochi) (Figs 23 and 24, KS 186). The North House was a substantial Roman residence above the north end of the so-called Unexplored Mansion (Flouda 2017, 353, fig. 6, n. 29). A portion of the house (20 m by 20 m) was first excavated during the Second World War (Flouda 2017, 353), with the site of the Unexplored Mansion being excavated further in the late 1960s and 1970s, when the post-Minoan material fell under the charge of Hugh Sackett (Sackett et al. 1992, vii). Sackett and his team excavated portions of five relatively well-appointed houses and a paved street in this area (Sackett et al. 1992).

Today, a 12.5 m-long section of the aqueduct's wall still stands to a height 1.5 m high (rising to 105.1 m amsl at its western end) at the northern end of the excavated area. The remaining exposed channel is just under 30 cm in width, with only one remaining capstone *in situ* at its western

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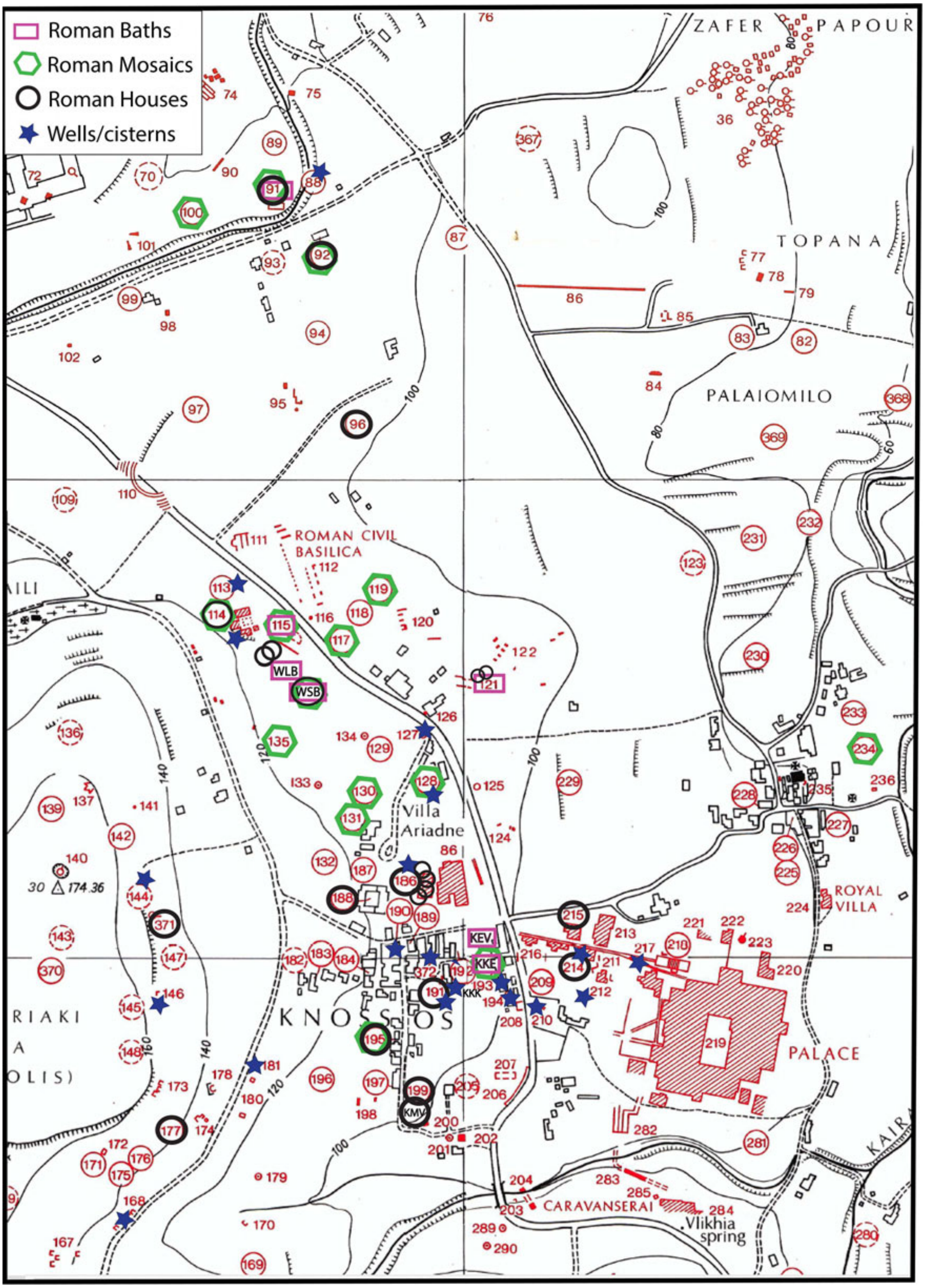

Fig. 24. Distributions of reported Roman houses, baths, mosaics, wells and cisterns within the marked area.

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extent.[30] For Sackett's excavation team, the aqueduct wall provided 'a convenient northern limit to the excavations' (Sackett et al. 1992, vii and 18). In 1992, Sackett described the aqueduct wall as follows:

> The walling [of the aqueduct] stood up to 1.50 m high at its south face, which also formed the outside wall of the North House, and had a total width of 2.50 m. The masonry was well constructed and used mortar between stones. The water culvert itself was 35 cms wide and had a considerable down gradient at this point running from west to east (0.50 in 10 m, or 1 in 20). Sherds from cleaning operations can be dated as late as the 4th century A.D. and indicate that the channel remained open even after the destruction of all the buildings in the excavated area. The strength of the structure, the care with which it was lined, covered and kept up, as well as the long continuity of its use, seem to support an interpretation as aqueduct rather than drain. (Sackett et al. 1992, 57–8; also see pl. 38*c*)

The wall elevation is composed of regularly shaped blocks set in neat rows with occasional small chinking stones to maintain linearity (see Popham and Sackett 1972–3, 50, fig. 2). The flow along the branch runs west–east with a drop of 0.4 m along its length, similar to the gradient noted by Sackett above. It is likely that this aqueduct branch tapped the civic water supply running on a south–north axis in the area of the Stratigraphical Museum. Sackett also came to this conclusion, noting that 'it is also pertinent that much later water channels have also brought water to Knossos from this direction along the contour at the foot of the Acropolis' eastern slope. Further excavation to the west should pick it up in that direction' (Sackett et al. 1992, vii and 18).

While no private baths were reported from any of the partially excavated Roman houses in the area of the Unexplored Mansion, structural bathhouse materials, including clay spacer pins manufactured in local clay, were discovered in late second-century AD secondary deposits and in wash covering the excavation (Sackett et al. 1992, 246, no. R3, 3a, pl. 217, and for U165, see 250–6). Their presence in a late second-century AD deposit (n. R3, 3a) points to an earlier bathhouse in this area.[31] In the nearby Stratigraphic Museum excavations, a series of architectural elements including *pilae* and terracotta pipes were thought to be 'reused from some adjacent, out of use or destroyed hypocaust and thus bath' (Warren 1987–8, 93, figs 27–8). The presence of an aqueduct branch in this residential area might indicate that either a public bathhouse lay somewhere in the vicinity or that the houses themselves were fitted with private bathing installations. Private bath suites were regular installations in elite Roman housing, and were even found in homes of the aspiring elite. A degree of relative wealth is on display in the interior decor of the Roman houses in the area of the Unexplored Mansion (Sackett et al. 1992, 53). Walls in the House of the Diamond Frescoes were lined with plaster imitating marble from Thessaly and Numidia (Sackett et al. 1992, 37–47; Paton 2004b, 453–5), and the North House contained possible mosaic bedding layers (Sackett et al. 1992, 49), while fragments of painted plaster and marble dado were found in collapse from a second storey, all of which point to reasonably prosperous residences (Sackett et al. 1992, 53), which might extend to private bathing fixtures.[32] Wardle classified a bathing facility in trench C of the K2K excavation at Knossos as the private bath suite of a larger unexcavated house complex (Wardle's Small Bath: WSB in Table 3, Figs 23 and 24; Wardle 2000; Forster 2009, 46; Kelly 2013, 138; Sweetman 2013, 174), while the same private classification was applied to other Roman bathing blocks on Crete, notably those at Myrtos, Minoa and Pachyammos (Kelly 2013, 143–55; forthcoming). Private bathing facilities have been identified in several more extensively excavated Roman house complexes on Crete, including the villa at Makryialos (Kelly 2013, 145), the House of Pheidias

[30] For illustrations, see Sackett et al. 1992, pls 4 and 40*a*.

[31] Sackett et al. 1992, 246, n. R3, 3a, pl. 217; Kelly 2013, 136–7; for their application in bathhouses, see Kelly 2004–5, 611–18.

[32] It is perhaps relevant here that Sackett et al. (1992, 30) interpreted a cistern and drain arrangement in the Southeast House connected to a soak away under the paved street as a water closet.

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Table 3. Reports of Roman baths at Knossos.

Bath labels	Identification	Location	Date	Sources
WSB: Knossos 2000, Wardle's small bath in Trench C.	Confirmed	Villa Dionysos field	Late 2nd or early 3rd century AD (Sweetman 2013, 174, nos 11–12; Kelly 2013, 138)	Wardle 1998; 2000; Sweetman and Grigoropoulos 2010, 340, 349, 351, fig. 1.
WLB: Knossos 2000, Wardle's large bath in Trench H.	Unconfirmed	Villa Dionysos field	Late 2nd or early 3rd century AD (Sweetman 2013, 173, no. 10)	Wardle 1998; 2000; Sweetman and Grigoropoulos 2010, 351.
KS 115 (semi-circular mosaic) labelled 'Roman mosaic, perhaps baths' in Evans 1928, plan, opposite 547.	Unconfirmed	Villa Dionysos field/Area of Civil Basilica	Roman	KS 115 The semi-circular form of the mosaic was originally marked on Evans 1899–1900, pl. 12; Evans 1928, plan, opposite 547; Sweetman 2003, 531, no. 16; Hood and Smyth 1981, 43; Morgan 2009, 49, n. 33.
KS 121 The bath reference is from Ralegh Radford's (1937) report (unpublished) on Roman Remains at Knossos (5).	Unconfirmed	Area of Civil Basilica	Roman	KS 121–2 Sweetman and Grigoropoulos 2010, 359; Hogarth (1899–1900b, 81, pl. 12 n. 15) recorded houses (14–16) and a larger building, perhaps a small temple (15); it is marked 'Small temple' on Evans' (1928) plan, opposite 547.
KKE Kambouraki Plot (connected to KEV)	Unconfirmed	Lowest area of Knossos village (Bougada Metochi)	Mosaic, Aurelian coins, pottery 1st–4th century AD (Sweetman and Grigoropoulos 2010, 345)	Knossos Logbook 111; Sweetman and Grigoropoulos 2010, 353, 372.
KS 91 The Apollinaris Mosaic	Unconfirmed	Venizelion Hospital	Late 1st century AD (Sweetman and Grigoropoulos 2010, 347)	KS 91; Sweetman 2003, 527, n. 9; Sweetman 2013, 169–73, pl. 9; Sweetman and Grigoropoulos 2010, 345, 348.

at Kissamos (Markoulaki 2009, 364–5) and House 2 at Eleutherna Sector I (Themelis 1994–6, 269, 268 for plan, pl. 11; 2002, 80).

The aqueduct skirting the western edge of the Villa Dionysos field

Despite a general lack of field evidence for the historic aqueducts along the roadway between the Caronissi Bridge and the village in 2019, an aqueduct is labelled further along this route in a series of twentieth-century plans, where it follows the road running above the village and skirting the western edge of the Villa Dionysos field, eventually turning north-east to link up with the main road to Iraklio. Slabs were visible on the surface of the track before the road was paved in the 1990s (Todd Whitelaw pers. comm.).

In Fyfe's map of Knossos, two architectural features along this trajectory are labelled 'Water Supply from Aqueduct': one at the crossroads above the village and another opposite the main entrance to the Venizelion Hospital.[33] The route is finally relabelled 'Venetian Aqueduct and Path' by 1928.[34] In 2021, a 115 m-long tract of later aqueduct walling was plotted opposite the entrance of the Venizelion hospital (Kelly 2022, fig. 2). Smyth also reported a channel in a trench in this location, and the top of this channel was 1 m below ground surface.[35] While the country road skirting the west side of the Villa Dionysos field may follow the Venetian and Ottoman-Egyptian lines, the Roman aqueduct may have run east of the road following the *c.* 115 m contour. In this position, it would have run lower than the road elevation but still above Wardle's baths (WSB and WLB in Table 3; marked on Fig. 24).

Urban development below the line of the Roman aqueduct

Private Roman houses have been recorded below the aqueduct line, with a distribution extending from the footprint of the upper Knossos village (KS 191, 195, 199, also KMV; Table 2), immediately north over the Unexplored Mansion (KS 186, including the five houses partially excavated by Sackett et al. 1992), in the surrounds of the Stratigraphical Museum (KS 188; Warren 1987–8), in the Villa Dionysos field (KS 114; Halbherr's excavations are summarised by Morgan 2009, 47–52; and WSB, with two further townhouses reported between them by Wardle 2000, Trench E) (Fig. 24).

Immediately east of the main road, Hogarth (1899–1900a, 81, nos 14–16, pl. 12) recorded houses and a larger public building (KS 121), which was subsequently labelled either a temple or a bath (Table 3). In 1981, the discovery of a villa (KS 96) and an inscription of VESPASI north-east of the so-called Civil Basilica (KS 112) prompted Hood and Smyth to describe the area as 'an important residential quarter in the 1st and 2nd centuries A.D.'. That this area was a Roman focal point was first recognised by Halbherr, during his 1885 excavation (see Morgan 2009, esp. 55) and supported by Hutchinson's rescue excavations of the mid-1930s, when statuary and mosaics were discovered east of the main road (see for example Hutchinson 1938–40, 23; Sweetman 2003, 534, no. 17, pl. 87*a–c*). Closer to the Venizelion Hospital, two Roman structures with mosaic flooring were reported as houses in the Knossos Survey (KS 91–2),

33 Evans 1899–1900, pl. 12; also labelled aqueduct on Doll's 1909 redraft of Fyfe's plan: Ashmolean Museum, Evans Architectural Plans, KA/6 b.

34 Evans 1928, plan, opposite 547; see also KS 52. In the plan accompanying the legal contract securing the transfer of Evans' property to the British School at Athens, dated 6 June 1926 (published by Panagiotaki 2004, 527, fig. 48:7), the country road running northward above the upper village is again labelled 'aqueduct' and features the same architectural angle at the road junction above the village. This aqueduct is mentioned earlier in the transactions concerning Evans' land purchases at Knossos on 6 of May 1905: Panagiotaki reports that Evans 'bought a house and land that contained a threshing floor and bordered the aqueduct (off SW corner of the Villa Ariadne property) and road of Bougada Metochi' (Panagiotaki 2004, 528, fig. 48:7; Christakis 2019, 205). Four years later, in 1909, 'Evans bought a vineyard, olive grove, garden and ruined houses that bordered his property on two sides (the Villa Ariadne area), the public road and the roads for Bougada Metochi and Fortetsa as well as the aqueduct' (Panagiotaki 2004, 528).

35 Knossos Logbook 11.10.1978. I extend my thanks to Todd Whitelaw for bringing this entry to my attention.

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

although KS 92 was also tentatively mooted as a possible public building; these seem to mark the northern extent of this recorded residential spread.[36]

Similar high densities of Roman urban residential housing have been recorded in other Cretan centres, not least Kissamos, where, thanks largely to the work of Stavroula Markoulaki, over 30 townhouses have been identified (and five baths), with mosaics recorded from 15 different plots (Markoulaki 2009; Sweetman 2013, 99). Roman construction at Knossos, however, has since been shown to be much more extensive than that envisaged by the 1981 Knossos Survey (and even the entire corpus of excavated Roman architectural materials in the valley) by the wide distribution of mosaic tesserae and imported marble veneer fragments recovered from across the entire northern sector of the city by the Knossos Urban Landscape Project (KULP) (Whitelaw, Bredaki and Vasilakis 2019a, 10–11, fig. 6).

The 1981 Knossos Survey demonstrated that, in the area just below the aqueduct trajectory, the distribution of private Roman properties (as outlined above) is interspersed with mosaic pavements (KS 91–2, 100, 114–15, 117, 119, 128, 130–1, 135, 195 and KKE), 'Roman buildings' (KS 105, 111, 113, 185, 189), 'Roman concrete' (KS 76, 84, 86, 90, 94–5, 98, 101–2, 111, 120, 122, 124, 135, 198), Roman statuary (KS 76, 93, 97 [colossal], 99, 104, 109, 113–14, 129, 132, 136 [colossal]), including at least two statues of Hadrian KS 97 and 114 and possibly Sabina KS 99 (Kotsonas 2016, 304–5, fig. 3; Karanastasi 2016, 108, fig. 8:9; Baldwin Bowsky 2017, 441–2), Roman inscriptions (KS 58, 59, 76, 93, 96, 99, 136, 168), numerous Roman wells (e.g. KS 88, 113–14, 127–8, 186, 193–4, 212, 372, but also throughout the cityscape), Roman tanks (notably KS 190–1, 210) and Roman roads (KS 116, 208, 211). This record is reinforced and supplemented by Roman materials found in the frequent small-scale rescue excavations conducted in trenches across the area, reviewed by Sweetman and Grigoropoulos (2010, 344–5, table 1). When these findspots are pinned against the backdrop of Roman tesserae plotted by KULP, we see a much more expansive density across the north of the site (Whitelaw, Bredaki and Vasilakis 2019a, 10–11, fig. 6).

The Roman residential architectural spread plotted by the 1981 Knossos Survey, extending from the upper Knossos village towards the Villa Dionysos, and further north, rests below the 115 m amsl contour on the eastern slopes of the Acropolis Hill (the Monastiriaki Kephala Hill), with relatively little clearly identified residential housing extending above this horizon.[37] While spreads of Roman material extend all the way to the summit, as confirmed by KULP (as cited in Morgan 2009, 54, fig. 6), the nature of this material has yet to be defined in terms of residential or public, Roman or Byzantine.

A large-scale geophysical survey conducted in 2015–18 detected terracing in the areas of Monastiriako Kephali and south of the Villa Ariadne (Christakis 2019, 229; Bennet 2017, 23–4). Sackett's team also observed a similar effect in the layout of the Roman houses in the footprint of the Unexplored Mansion, which were terraced into the hillside and often laid out over different levels.[38] To a more gradual extent, the Villa Dionysos and Wardle's baths are laid out

[36] The Apollinaris Mosaic (KS 91) lies just under a kilometer north of the village.

[37] While only two possible residential structures have been tested by excavation above the country road, two cisterns were reported above this horizon (KS 144 and 146). Hogarth (1899–1900a, 81) mentioned a large Roman cistern or reservoir 'under the summit [of the Acropolis Hill] on the north east-slope', south of the cemetery, which he associated with conduits at Metochi (Knossos Village), interpreting them all as an integrated but extended system. He attributed the function of this structure off the summit of the Acropolis Hill as 'a larger Roman cistern or reservoir for the supply of water to the town below' (Hogarth 1899–1900a, 81, pl. xii; KS 144). I am grateful to Todd Whitelaw for also bringing to my attention the existence of a niched fountain (constructed of neatly cut stone blocks topped with a brick fanned arch) located on the NE slopes of the hill (above the country road due west of bath WSB) and, further north of this, a channel and a substantial support wall running east–west (Todd Whitelaw pers. comm. 2018; Trainor 2019, 4). These notable water-related architectural installations point to sophisticated water collection but are too high to be directly fed by the Roman aqueduct running from Fundana; however, they constitute an important collection and/or supply system which clearly merits further attention (see Trainor 2019, 4; for a second higher supply system feeding Knossos see Kelly 2022, 139–51).

[38] Sackett et al. 1992, 17–18. The Roman bathing block at Myrtos was laid out over coastal terraces providing a range of viewing points over the sea (Kelly forthcoming).

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

over terraces set into the hillside. In light of this evidence, we might imagine a series of wealthy terraced residences and complexes laid out over the hillside, descending from the 115 m contour towards the main Knossos–Iraklio road, the Leoforos Knossou.

As noted above, the area around the so-called Civil Basilica (KS 112; see Fig. 24) has long been identified as an affluent civic focus (Cadogan 1992, 134; Paton 2004b, 453–5; Sweetman and Grigoropoulos 2010, 349–50; Paton 2022, 1). Sweetman and Grigoropoulos (2010, 350) report on 'buildings of an increasingly monumentalized nature the nearer they were to the Civil Basilica' along a line of DEYAH trenches leading from the Venizelion hospital. In addition, they list a series of public imperial buildings in the zone around the so-called Civil Basilica, including the theatre (KS 110), a monumental structure with an apse (KS 111) and potentially public and private baths (Sweetman and Grigoropoulos 2010, 349).

Urban development immediately below the 115 m amsl contour on the lower slopes of the Acropolis Hill may have been influenced by access to the civic water supply. In Roman Chersonisos, the operation (and most likely the construction) of the city's six public baths (and potentially numerous private facilities) was facilitated by the installation of a public aqueduct (Galanaki et al. 2006, 269; Papadaki, Triantafyllidi and Grigoropoulos 2010). Over 100 m south of the Villa Dionysos, a small bathing complex was classified by the excavator, Kenneth Wardle, as the private bath suite of a wealthy townhouse (WSB in Table 3; Kelly 2013, 138; Sweetman 2013, 174; Forster 2009, 46; Figs 23–4). This bathing block is located at a level of *c.* 105 m amsl (floor level of room 1), *c.* 40 m east of the country road skirting the 115 m amsl contour (Tomlinson 1995–6, 40–1, fig. 23; Sweetman and Grigoropoulos 2010, 340, fig. 1; Christakis 2019, 209). The excavated portion of the bathing block measured 250 m^2 (Forster 2009, 46–8). It is relevant that the room set at the highest point in the complex and closest to the country road was a cistern (room 1). This cistern sat adjacent to the largest room of the exposed complex, fitted with a net pattern floor mosaic (room 3), while a sunken plunge pool was also identified, along with two hypocaustal areas and another mosaiced floor.

Immediately south-east of the Villa Dionysos, Wardle partially unearthed a 6 m-high wall associated with a fragment of mosaic and marble veneering, which he interpreted as part of a potentially massive bathhouse (WLB on Table 3 and Fig. 24). The wall was traced for 30 m, suggesting a complex occupying an estimated area of 900 m^2, which Wardle (2000; 1998, 47) suggested had two or possibly three storeys. The wave-crest motif running flush with the wall measured 0.25–0.30 m in width and constitutes the largest example of this border motif on the island (Sweetman 2013, 173, no. 10), indicating a room of considerable size. While the identification of this structure as a bath is not certain, it would be fitting that a large public bathhouse would be sited in such a well-positioned public quarter laid out just below the civic aqueduct of Knossos.

In the map of Knossos published in 1928 (and originally marked on Fyfe's 1900 map), a semi-circular mosaic found directly across the main road from the so-called Civil Basilica was labelled by Evans 'Roman mosaic perhaps baths' (Evans 1928, opposite 547). Hood and Smyth considered this semi-circular mosaic and 'a stretch of concrete wall running parallel with the road immediately south of no. 114 [the Villa Dionysos]' as part of the same complex (Table 3:KS 115; Sweetman 2013, 177–8, no. 16). The wall to which they refer is likely to be that of WLB, which sits in this exact location; however, that Wardle's wall (with its wave-crest mosaic) is part of the same complex as the semi-circular mosaic is unconfirmed.

At least in the second century, water from the public supply may have been conducted to a robust cistern, W27, in the south-west corner of the Villa Dionysos (Paton 2022, 28–9, fig. 17). Paton (2022, 34–5) suggests that this supply may have serviced a private bath suite within the villa, along its southern extent, part of which may still be in place. Another shallow brick-built tank, lined with *opus signinum*, was located immediately south-west of the villa (Paton 2022, 35–6, fig. 21). A pipe (14 cm diameter) conducted water to the tank (exposed for 0.75 m by 0.80 m) from further west (Kelly 2013, 148; Paton 2004a, 285). The villa's placement, the level of its central courtyard at roughly 100 m amsl, the substantial cistern to the south-west of the *oikos*, and the elevated tank located to the south-west of the site, would all suggest connection to the public supply (Paton 2004a, 282). The water feature in the courtyard and the lead pipes enclosed in stone-built channels below the surface of the peristyle point to a sophisticated water network within the house (Paton 2022, 11). The presence of wells in the villa, notably Well A, present a supplementary supply with limited, or even specific, application; Paton (2022, 10) attributes Well A to watering the courtyard garden. That well water would have to be manually hauled up points to the presence of servants within the household.

The degree of comfort enjoyed in private Roman homes connected to the civic aqueduct supply is demonstrated at Kissamos, in western Crete, where the two-storeyed House of Pheidias is fitted with six mosaic floors and its own private bathing suite (Markoulaki 2009, 364–5; 2000; Andreadaki-Vlazaki 2002, 270; Sweetman 2013, 268, no. 207). The Villa Dionysos (KS 114), with its peristyle design, mosaic flooring, and notable statuary is clearly a house of some standing.[39] That this villa, decorated with some of the finest mosaics seen on Crete (Sweetman 2007, 68, 73), would have been fitted with a private bath suite, as yet unidentified, is in keeping with the trappings of houses of this calibre both on Crete and across the empire. A quantity of spacer pins reported by Paton (1998, 127; 2022, 14, 25, 35) in deposits overlying the Villa Dionysos need not have been transferred from another facility and may have originated from an installation within the wider private complex.

Water pipes lining the Roman road above the Royal Road

But water distribution and access was not limited to this urban quarter, and water was conducted downhill in both pipes and open channels in the direction of the Palace. A Roman cistern was discovered by Hutchinson, east of the village, in the modern carpark of the Palace (cited in KS 210; Christakis 2019, 212), while directly opposite the modern entrance to the Palace, Hutchinson also reported a possible Roman road (KS 208).[40]

Evans also unearthed, 118 metres along the Royal Road, a section of Roman road running on the same axis 2 m above the Minoan road level, an overlay which Evans (1903–4, 50, 52, figs 17–18) viewed as a 'historic coincidence'. He followed this stretch of Roman roadway for 9.2 m and temporarily preserved it for 8.5 m (Evans 1903–4, 50 and 52). Evans (1903–4, 52) noted that

> on the South side of the roadway run three conduits or water-pipes. Two of these, formed of a kind of cement mixed with potsherds, are square in section and laid on a mortar bedding. The other is round, and consists of sections of terra-cotta piping fitted into one another, and with their necks pointing East, showing that the flow of water was in this direction.

In 2000, two parallel lines of *opus signinum* still adhered to a surviving upper section of the wall flanking the Royal Road (Kelly 2004, vol. 2, 34, no. 8.10, vol. 3, pl. 19*a*).

The Roman cistern north of the Theatral Area of the Palace

Evans returned to the area almost 30 years after first noting a 'Roman conduit' leading to the west side of the Theatral Area in the Minoan Palace (Evans 1935a, 49; KS 217). Over 200 m east of the upper village of Knossos (Bougada Metochi), a sizeable cistern is positioned to the north of the Theatral Area in the Minoan Palace where it sits at an altitude of 93 m amsl (KS 217) (Fig. 25). These remains are all that is left of the Roman cistern dynamited by Evans (1902–3, 106) at the turn of the century. While Evans was aware of the Roman water distribution system in the Palace surrounds, he did not always appreciate this later material trace, and he complained that this Roman cistern extending over the Theatral Area could only be removed 'by a long process of blasting' (Evans 1902–3, 106; 1935a, 18). Evans (1902–3, 106) described 'a huge flooring of

[39] Paton 2004b, 453; Sweetman and Grigoropoulos 2010, 351; for the depositional context of the statue of Hadrian see Evans 1935b; Kotsonas 2016, 304–5, fig. 3; Paton 2022, 19.

[40] This road was traced closer to the Taverna, while the road by the NE corner of the Little Palace is also post-Minoan (Todd Whitelaw pers. comm.).

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

Fig. 25. Roman cistern to north of Theatral Area of Palace, photographer facing east.

Roman cement … 65 centimetres in thickness and intruding on the area to be excavated to the extent of some 60 square metres'.[41]

The thick layer of *opus signinum* coating the cistern (Fig. 25) is comparable to *opus signinum* linings recorded along the length of the Roman aqueduct and its related cisterns. But why was this cistern positioned here and what civic quarter did it serve? In practical terms, this large cistern could serve any Roman structures nearby founded below its elevation of 93 m amsl, but recorded urban infrastructure in the immediate area is lacking. While Roman houses were reported immediately to its west (KS 214 and 215),[42] the nearest documented Roman levels are in the House of the Frescoes area (Whitelaw pers. comm.). Although at the considerable

[41] 60 m^2 is a substantial area, measuring about four times the size of a parking space; unfortunately the depth of the cistern remains unknown.

[42] Numerous Roman coins are published from Warren's Royal Road South excavations (Ashton 1989).

distance of 300 m to the north-east, a Roman structure fitted with a mosaic did overlook the river from its elevation of 70 m amsl (KS 234 and 236). This structure would have had a particularly attractive terraced aspect, located just below Makryteikhos village overlooking the Katsambas River with a view of the slopes of Ailias on the far side of the wide valley (the same view enjoyed by residents of the Royal Villa over a millennium earlier).

DISCUSSION

How much water was being delivered to Roman Knossos and what implications did this have for the city's urban footprint? In 1892, Fundana's rate of flow was listed at 200 *massoures* (approximately 1296m^3/day; see Kelly 2022, 124, table 1 for calculations), twice that of any other spring in the district. The rate of flow reported in 1892 (TAH Z8 no. 4356), while presenting a static historic figure, is comparable to one of the three main sources for the Gortyna aqueduct in the Zaros-Gergeri region, that at Sternes, which Giorgi (2016, 25, 30) reported produced anywhere from 1200–3600m^3/day, depending on the season. Giorgi (2016, 30, 60 n. 169) envisaged a combined flow rate of 8400–14,400m^3/day for all the springs which potentially supplied the aqueduct of Gortyna (a figure she compared to that of Carthage at 17,000m^3/day). At Gortyna, the lower estimates for the population range between 17,000 and 34,000 (Giorgi 2016, 60). Giorgi (2016, 60, n. 175) estimated that the total amount of water available per capita per day in Roman Gortyna was 280 litres for the lower population range.[43]

Both pre-industrial and modern data show that 20 litres of water is the minimum daily quantity needed per capita per day to meet basic drinking and minimum hygiene needs.[44] It is important to note, however, that basic drinking needs were already met in the pre-Roman phases of evolving cities, and by inference, Roman aqueducts were usually designed to meet a need beyond these basic expectations. Giorgi presents a huge volume of water being delivered to Gortyna by aqueduct, and she reasonably questioned why so much water (effectively all the water from the southern Ida catchment basin) was conducted to the Roman city (Giorgi 2016, 60–6, n. 169). She identified (1) the baths, (2) private elites and the upwardly mobile, and (3) irrigation in the Mesara as the biggest consumers of this excess. In the Roman period, baths were probably the greatest consumers of water within the urban footprint (Hodge 1992; Fabre et al. 1992; Fabre, Fiches and Paillet 2000), as were mosques and their associated baths under Ottoman and Ottoman-Egyptian rule, but the aqueduct could also simultaneously feed multiple drinking fountains – for the full array of amenities supplied by aqueduct in a nineteenth-century Ottoman city, see Ertürk, Şeker and Öztürk (2013) on Safranbolu in Turkey.

According to findings from KULP, Whitelaw and Trainor have estimated that by the Middle Roman period, the population of Knossos shrank to 7000–10,000 people, presenting a potentially considerable drop from the 10,000–17/18,000 individuals calculated for the Classical and Early Hellenistic periods.[45] Based on these population estimates, the civic aqueduct of Roman Knossos was delivering a minimum daily water supply per capita of 130 litres at the peak of its population.[46] Any excess water could have fed any potential bathhouses identified within

[43] While calculations have varied, Ohlig (1996, 22) suggested a daily per capita availability at Pompeii of 200–400 litres. See Chanson 2002, 49–50 for modern comparanda.

[44] Stenton and Coulton 1986, 55; Giorgi 2016, 60–1; Lalonde 2019, 184; WHO and UNICEF 2000. This figure was also cited in 2000 as 'reasonable access' by the WHO/UNICEF Joint Monitoring Programme, which produces the Global Assessment of Water Supply and Sanitation data.

[45] Whitelaw, Bredaki and Vasilakis 2019b, 11; Trainor 2019, 1–2, 4–5; for comparable population fluctuations in late 16th- and 17th-century Iraklio, see Kelly 2022, 120. Iraklio's population in 1838 was 12,000, although Bowring (1840, 157, 184) also notes 19,000 in Malaris 'in which Candia was located'.

[46] It is likely that much more water was being captured by the Roman aqueduct, as the rates of flow in 1892 were summer readings while other springs (like that of Miliara and/or perhaps Karydaki) may also have been tapped. Chalkiadakis (2012, 461) provides a higher reading of 250 *massoures*, which would provide 160 litres per capita per day. Spyropoulos supplies data on water availability in early 18th-century Iraklio, reporting that in 1719,

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

the city's footprint (see Table 3), while the existence of further installations is clear from structural bathhouse materials (including *pilae*, spacer pins and terracotta pipes) reported from the excavations of the Unexplored Mansion (Sackett et al. 1992, 246, no. R3, 3a, pl. 217; Kelly 2013, 136), the Stratigraphic Museum (Warren 1987–8, 93, figs 27–8) and the Villa Dionysos (Paton 1998, 127; 2022, 14, 25, 35).

Public aqueducts facilitated an unprecedented ease of access to drinking water, served as an urban cooling system,[47] enhanced the urban aesthetic and guaranteed mountain purity within the heart of the city (Rogers 2018, 175, Argos, 176–7, Corinth; Leigh 2018, 229–31, Athenian Agora). While altitude was often a key determinant when choosing a spring to tap for aqueduct construction, abundance and perceived purity of upland spring water also constituted important considerations.[48] Aqueducts did not displace all other forms of water collection and access, local springs were still tapped and wells and rainwater collection systems still operated within the city, but connection to the civic supply afforded a level of comfort and undoubtedly a measure of prestige.

Beyond Crete, we know that the benefits were not exclusively enjoyed by city-dwellers. Bannon highlights that while the Roman state controlled these natural sources, it could also grant access and withdrawal rights to private individuals residing within both the city and its surrounding countryside.[49] Statius in *Silvae* 1.3 celebrates the supply of the villa of Manilius Vopiscus at Tivoli, detailing its conduction in lead pipes from the Aqua Marcia across the Aniene River (*Silvae* 1.3.66–9; Putnam 2019, 86–7; Thomas and Wilson 1994, 146–7).

As noted, Giorgi considered the irrigation of the Mesara as a possible application for the residual water delivered to Gortyna. It is at least possible that at Knossos run off from the aqueduct supply was deployed for the irrigation of crops and orchards cultivated in the city's hinterlands west of the Katsambas (although we must also allow for the large cemeteries in the city's immediate surrounds). At Knossos, Sweetman and Grigoropoulos (2010, 340) observed, mainly on the positioning of mortuary remains in the site's wider surrounds, 'that the city occupied in some form the extent of the valley floor, some 2500 m north to south and 1500 m east to west; that is to say an area 25 times greater than that which has been explored in detail' and that a significant portion of this area would have comprised agricultural land. Data from KULP suggest that the urban area shrank from 120 ha to 90 ha from the Hellenistic to the Early Roman period, and even further as the Roman period progressed (Whitelaw, Bredaki and Vasilakis 2017, 12; 2019a, 10–11, fig. 6; Trainor 2019, 4–5; Christakis 2019, 201 n. 25).

Our 2019 field inspection plotted a length of 12.42 km for the Roman aqueduct of Knossos. The physical length of a water supply was correlated with quantities of raw materials and the time and manpower needed to complete its construction, factors which fed directly into costs (Leveau 2001, 85). The length of the Roman aqueduct supplying Knossos lies at the shorter end of the civic scale, but the construction of its 1 km-long Roman aqueduct tunnel would, nonetheless, have constituted a major consideration for the aqueduct's cost of construction. As already noted, the tunnel was over twice the length of the notorious tunnel along the Saldae aqueduct (see Table 1). Chanson and Leveau each estimated that the construction of Roman

118.5 *massoures* supplied a city of approximately 10,500–13,000 people (Spyropoulos 2018, 107; based on calculations by Ertürk, Şeker and Öztürk 2013, 747), but, over the next three years, Iraklio's running water capacity doubled, reaching a total of 286.75 *massoures* (Spyropoulos 2018, 108; Stavrinidis 1984, 119–21; 1985, 239–41; TAH 16 n. 45, Z8 nn. 71–2).

[47] Rogers 2018, 183; see Statius *Silvae* 1.5.26–7 where the Aqua Marcia delivers coolness: *Marsas ... niues et frigora ducens / Marcia ...* .

[48] Frontinus, *De Aquis urbis Romae*, 89–94. Altitude, abundance and purity were the three factors promoting the springs at Karydaki for the Venetian aqueduct supply of Candia (Iraklio), as noted by Morosini in his 1629 report (Moresini, *Relazione* n. 12, in Spanakis 1950, 28).

[49] Bannon 2017, 85; Martial, *Epigrams* 9.18 and, for illegal tapping to water gardens, see Frontinus, *De Aquis urbis Romae*, 75.3.

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

civic aqueducts could amount to a gigantic undertaking often involving army personnel (both for labour and engineering expertise) with costs of 1–3 million sesterces per kilometre.[50]

Hero cautioned against excessive expenses incurred from needlessly lengthy trajectories in his *Dioptra* 6 (Lewis 2001, 265). Our 2019 fieldwork suggests that careful planning underpinned the trajectory of the Roman aqueduct supplying Knossos. Ancient sources refer to topographic surveys conducted prior to the construction of aqueducts to identify sources and plot the most cost-efficient functional trajectories in the field.[51] We know that the route of the Venetian aqueduct of Candia (Iraklio) was surveyed intensively prior to any ground being broken (Kelly 2022, 122–3; Gerola 1932–40, 14–16; Moresini, *Relazione* n. 12, in Spanakis 1950, 28).

In Hero of Alexandria's first-century AD work on the dioptra, one of the mathematical agents used is a surveyor who is laying out a watercourse and has to gauge the height difference between two points (*Dioptra* 6.1–21; Roby 2018, 73–4; Lewis 2001, 263–5). The second-century AD inscription found in Lambaesis, mentioned above (*CIL* VIII 2728), informs us that the military engineer, Nonius Datus, surveyed the route of the Saldae aqueduct, stating:

> Therefore I, who had first made the survey, had decided on the route of the aqueduct, had arranged for it to be done according to the plan which I had given the procurator Petronius Celer, completed the work. (translation Cuomo 2011, 145)

Having the army on hand was particularly advantageous for large-scale construction projects of any period: its presence afforded expertise, an organised skilled workforce and access to specific tools and materials.[52] At Autun, in Gaul, the orator Eumenes gave thanks to the emperor for deploying the army to repair the aqueduct:

> to work for our profit in the goodwill of a guest's gratitude and make waters that had ceased to flow, and new rivers as well, pour forth upon the withered vitals, as it were, of the exhausted city. (Eumenius, *Oratio pro instaurandis scholis, oratio* 4, translation Nixon and Saylor Rodgers 1994, 155–6; also cited in Leveau 2001, 89)

The completion of any given construction project might not go as planned, and even with military input, the tunnelling project along the Saldae aqueduct stalled (mentioned above); the aqueduct was only inaugurated in the early 150s, over 13 years after the route was first planned in AD 137, following a series of delays and mishaps, perhaps aggravated by the long absences of the original surveyor who had since retired (Cuomo 2011, 147; *CIL* VIII 2728). Philostratus in his *Life of Herodes* Atticus tells us that he secured three million drachmae (or 12 million sesterces) from Hadrian to build an aqueduct for Alexandria Troas (*Lives of the Sophists* 2.1.2), but as costs spiralled to seven million drachmae, his father stepped in to make up the shortfall (of 16 million sesterces) for the completed project (Leveau 2001, 90). Pliny (*Letters* 10.37) relays disastrous costs at Nicomedia, where 3,329,000 sesterces was spent on an unfinished aqueduct project, with a further two million raised in taxes squandered on a second abandoned project. Finally, Pliny (*Letters* 10.37), on locating a potential spring, asks Trajan for a skilled engineer or architect to be sent out to oversee the aqueduct project, to prevent a repetition of two previously disastrous attempts.

While it is hazardous comparing costs from one period to another, we do know exactly how much was, at least, budgeted for the construction of the nineteenth-century aqueduct supplying

[50] Chanson 2002, 43; Leveau 1991. Schram (2020) presents a range of literary and epigraphic evidence available on the subject of cost. The model could be downsized, however, and the 400 m-long Roman aqueduct at Malia on Crete could have been completed rapidly (Kelly 2004–5, 610, 621, fig. 5; for smaller costings also see Bannon 2009, 67–9).

[51] In these accounts, a *librator* was a leveller or surveyor, while an *aquilex* or conduit master was a man employed to find water sources (O'Connor 1993, 38).

[52] O'Connor 1993, 42. I am indebted to Pavlina Karanastasi for first suggesting the army's potential involvement in public building projects in Crete.

Iraklio: Bowring's report of March 1838 specifies that Mehmet Ali allotted 5000 Ottoman lira (henceforth *l*) to the construction of the aqueduct.[53] This amount is reiterated by both Raulin and Rashed, who put the cost of the restoration project at 500,000 *piastres* (125,000 francs) or 500,000 *grosia* or *kuruş*, respectively (Raulin 1867, 58 and 144; Rashed 1978, 113; Strataridaki, Chalkiadakis and Gigourtakis 2009, 4 n. 30). To put the expense into some form of perspective, in 1838 'The receipts on the island did not exceed on an average 400,000 dollars, or 80,000*l*, of which one-fourth was paid to Mustapha Pacha' (Bowring 1840, 154). Clearly, in 1838, 500,000 *grosia* (or 5000*l*) was a substantial amount of money, but, even so (and allowing for budget overruns), the return on the nineteenth-century aqueduct construction project must have far exceeded (or at least was expected to exceed) its cost over time. Moreover, the discovery of the Roman tunnel in the nineteenth century would have significantly lowered costs, and the project is repeatedly referred to as repair and reconstruction work, presumably of the older aqueduct. Knowledge of the existence of the Roman tunnel dispensed with a laborious boring scheme, while the extended Roman aqueduct served as a blueprint for the later trajectory, the construction of which was largely a matter of consolidating the Roman remains.[54] Spanakis reported that the Egyptian army were deployed to clean out the Roman tunnel at Skalani in 1838/9 (Spanakis 1981, 92; 1990, 48; see also Strataridaki, Chalkiadakis and Gigourtakis 2009, 4; Chalkiadakis 2012, 460). Spyropoulos notes that by the eighteenth century in Iraklio (Kandiye), the military were not only responsible for, but highly invested in, the functioning of the water supply; the 1719 records for the city demonstrate that military and administrative elites constituted the majority of private individuals who had access to running water (Spyropoulos 2018, 105, 107, citing Stavrinidis 1984, 48–51; TAH 15 nos 266–8).

The extent of the Roman aqueduct's route from Fundana demonstrates that the authorities at Knossos felt at liberty to construct an aqueduct through swathes of land to the south, but what underpinned this license to exploit such a relatively far-flung spring in the Roman period, and for that matter, what authoritative action sealed legitimate ownership of any spring in the Roman period? A measure for securing claim to spring water in the private sphere is outlined in an inscription from Viterbo, in Lazio, central Italy, where owning the land in which the spring rises and through which any associated infrastructure passes underpinned rights to that supply (*CIL* II 3003; Bannon 2009, 73, 136; 2017, 62 and 65–7). The inscription records that Mummius Niger Valerius Vegetus, the proprietor of the Villa Calvisiana, bought the land surrounding a spring and a 9 km corridor of land, cutting through nine estates, with the eminent owners all listed in the inscription, to facilitate the construction of an aqueduct to water his estate (Marzano 2007, 170, n. 64; Campbell 2012, 96).

If land ownership was a prerequisite for the control of a spring, then we might comfortably assume that the territory of Roman Knossos extended sufficiently far south to lay claim to this relatively remote resource. Unfortunately, no dedicatory inscription for the Roman aqueduct survives. That Knossian territory extended well into the lower reaches of the Juktas foothills is implied, however, through both the text and findspot of an inscription discovered in 1969, at Karnari, a village located 10 km to the south of Knossos (Ducrey 1969, 846, no. 3). The text outlines a dispute of AD 84 concerning a citizen of the Knossian colony, Plotius Plebeius, and some Capuan land-holdings (praefectura Campana), which bordered lands owned by the complainant (Iraklio Museum AE 1969/70, 0635; España-Chamorro 2021; Paton 2004b, 451–2; Rigsby 1976, 319; Ducrey 1969; Elliott 2004). The original findspot of the boundary marker at Karnari is relevant as it marks an extensive territorial spread encompassing the Juktas foothills and their numerous water sources (España-Chamorro 2021, 391).

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[53] Bowring 1840, 162. For the cost of the Venetian aqueduct supplying Iraklio see Kelly 2022, 122 n. 35.

[54] The Venetian aqueduct did not tap the spring at Fundana; instead, Morosini combined the waters of at least three springs around Epano Archanes to meet the demand for Candia (Kelly 2022, 124; Moresini, *Relazione* n. 12, in Spanakis 1950, 28). That the Venetian engineers were obliged to funnel together waters from several springs (and build a substantial bridge at Karydaki) to supply Iraklio, and their documented fear of the exorbitant costs of a new tunnelling project (Kelly 2022, 122), would suggest that they were unaware of the Roman tunnel's existence. Similarly, in the earlier Ottoman periods on Crete (1669–1830), the Fundana spring was not tapped (Strataridaki, Chalkiadakis and Gigourtakis 2009, 4).

Beyond land ownership, Bannon noted that under Roman law 'any work or construction around the water supply could be interpreted as an expression of the owner's right to the water' (Bannon 2017, 66). In this regard, Spyropoulos' (2018, 110) conclusion for his study of eighteenth-century Iraklio has resounding relevance for diachronic aqueduct studies:

> Their origins notwithstanding, the tactic used by all these elites was similar: They claimed the water of all the springs discovered in the vicinities of their cities by creating infrastructure connecting the former to the latter. After ensuring the appropriation of a large amount of water resources for their own establishments, they provided the rest of the water for public use – mainly through private endowments – thus presenting themselves as benefactors in the eyes of the local populace.

In this light, the Roman aqueduct supplying Knossos served as an architectural measure of territorial reach, a physical form of referencing that could be harnessed to serve the Ottoman-Egyptian regime many centuries later.[55] We see that, ultimately, aqueducts were not just physical constructions independent of the social and institutional frameworks of the period in which they were constructed and functioned, but rather were intricately connected to the varied lifestyles of the communities that they served.

ACKNOWLEDGEMENTS

Firstly, we must thank the staff of the Ephorate of Antiquities of Heraklion for allowing us to walk the aqueduct route in the first place and for their many kindnesses while in Crete. We give particular thanks to director, Vasiliki Sithiakaki, and both Eliza Kavoulaki and Eleni Kanaki, who helped us so much while we were in Crete. We are also indebted to Eleni Tsiknakou and Christina Papoulia at the Irish Institute of Hellenic Studies at Athens for their unfailing support and administrative assistance. We thank Kostis Christakis, Knossos Curator, for his care and hospitality while we resided at the Knossos Research Centre in 2019. We owe a debt of gratitude to Todd Whitelaw for editing this work so meticulously and for taking us to task over several points. We must extend this thanks to Peter Liddel for his endless patience and diligence with the many rewrites (and for humouring a wordy acknowledgement section). Hubert Chanson was also kind enough to read and discuss the work at length at an early stage. Similarly, Eustathios Chiotis was very generous with his expertise on water tunnels. Enoch Cheng and Nadia Coustinas have also kindly assisted at the initial and final stages of this publication. We also warmly thank the Istituto Veneto di Scienze, Lettere ed Arti, for permission to publish beautiful images from their collection (Fondo Giuseppe Gerola, Copyright Istituto Veneto di Scienze, Lettere ed Arti, all rights reserved). While out in the field in 2019, we were welcomed and assisted by many locals, including Artemis Kokkinou, her father, Manolis Kokkinos, and Manolis Vasilakis, who all shared their archaeological knowledge with us and provided us with a range of Cretan seasonal harvest fruits (including almonds, walnuts and pomegranates, and some Cretan aloe vera). On subsequent field checks (in 2022) Amanda Kelly was greatly assisted by Mara Panagiotaki, Stelios Manolioudis, Manolis Afrathianakis, Zacharias Aletras and Anna Moles. While walking the aqueduct route, we have experienced truly Homeric philoxenia from the numerous locals (harvesters, hunters and homeowners alike) that we met along the way. As always, we are deeply indebted to The Gerda Henkel Foundation as none of this would be possible without their funding.

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[55] For the role of the Venetian aqueduct of Iraklio in cementing Morosini's political career, see Fortini Brown 2021 and Kelly 2022.

REFERENCES

Unpublished sources

Knossos Logbook = unpublished logbook of archaeological finds and rescue excavations from the Knossos valley since World War II, in the Archives of the British School at Athens.

Radford, C.A.R. 1937. Report from Mr Ralegh Radford on Roman remains at Knossos, at the Knossos Research Centre.

Published sources

Abdrbba, M.O.M. 2019. 'Water supply systems in Cyrenaica during the Greek and Roman periods: Cyrene in context', *LibSt* 50, 99–105.

Andreadaki-Vlazaki, M. 2002. "Κέντρο Υγείας", *Κρητική Εστία* 9, 270–1.

Androvitsanea, A. 2018. "Το Οθωμανικό Σύστημα Υδροδότησης – Η Πόλη του Ρεθύμνου", The Department of History and Archaeology, University of Crete (available online <https://elocus.lib.uoc.gr/dlib/c/e/f/metadata-dlib-1535526909-980845-26514.tkl> accessed January 2023).

Ashton, R.H.J. 1989. 'Knossos Royal Road South 1971 and 1972 excavations: the coins', *BSA* 84, 49–60.

Baldwin Bowsky, M.W. 2017. 'Tiberius and the Asklepieion at Lissos (Crete): petition and response, image and power', *Mediterraneo Antico* 1–2, 395–444.

Bannon, C. 2009. *Gardens and Neighbors: Private Water Rights in Roman Italy* (Ann Arbor, MI).

Bannon, C. 2017. 'Fresh water in Roman law: rights and policy', *JRS* 107, 60–89.

Baykan, N.O. and Tanriöver, Y.E. 2006. 'Water supply system of the ancient city Tralleis', in G. Wiplinger (ed.), *Cura Aquarum in Ephesus*, vol. 1 (Österreichisches Archäologisches Institut; Vienna), 133–6.

Bayraktar, E. 2005. 'The implementation of Ottoman religious policies in Crete 1645–1735: men of faith as actors in the Kadı court' (unpublished MA thesis, Institute of Economics and Social Sciences, Bilkent University).

Bennet, J. 2017. 'The work of the British School at Athens, 2016–2017', *AR* 63, 9–25.

Bowring, J. 1840. *Report on Egypt and Candia: Addressed to the Right Hon. Lord Viscount Palmerston* (London).

Burdy, M.J. 2001. 'Les ponts des siphons de l'aqueduc romain du Gier, à Lyon. Tablier incliné et piles élégies', *BAntFr*, 38–55.

Cadogan, G. 1992. 'Knossos', in J.W. Myers, E.E. Myers and G. Cadogan (eds), *The Aerial Atlas of Ancient Crete* (London), 124–47.

Campbell, B. 2012. *Rivers and the Power of Ancient Rome* (Chapel Hill, NC).

Chalkiadakis, E.G. 2012. 'The water supply to Heraklion, Crete, Greece from the Ottoman period (1669) to the present; the modern aqueduct and the ancient springs', conference paper at 3rd IWA International Symposium on Water and Wastewater Technologies in Ancient Civilizations, Istanbul, Turkey, March 22–24, 2012, pp. 459–66 (available at <www.researchgate.net/publication/337304962_The_Water_Supply_to_Heraklion_Crete_Greece_from_the_Ottoman_Period_1669_to_the_Present_the_Modern_Aqueduct_and_the_Ancient_Springs_in_3rd_IWA_International_Symposium_on_Water_and_Wastewater_Technolog> accessed January 2023).

Chanson, H. 2000. 'Hydraulics of Roman aqueducts: steep chutes, cascades, and dropshafts', *AJA* 104.1, 47–72.

Chanson, H. 2002. 'Certains aspects de la conception hydraulique des aqueducs romains', *La Houille Blanche – Revue Internationale de l'Eau* 6/7, 43–57.

Chiotis, E.D. 2018. 'The Hadrianic aqueduct of Athens and the underlying tradition of hydraulic engineering', in G.A. Aristodemou and Th.P. Tassios (eds), *Great Waterworks in Roman Greece. Aqueducts and Monumental Fountain Structures: Function in Context* (Roman Archaeology 35; Oxford), 70–97.

Christakis, K. 2019. 'The emergence of a metropolis: the excavations of the British School at Athens in the valley of Knossos', in N.Chr. Stampolides, E. Papadopoulou, I.G. Laurentzatou and I. Phappas (eds), *Crete. Emerging Cities; Aptera – Eleutherna – Knossos* (Athens), 196–231.

Cuomo, S. 2011. 'A Roman engineer's tales', *JRS* 101, 143–65.

Ducrey, P. 1969. 'Trois nouvelles inscriptions crétoises', *BCH* 93, 846–52.

Elliott, T. 2004. 'Epigraphic evidence for boundary disputes in the Roman Empire' (unpublished PhD thesis, University of North Carolina, Chapel Hill).

Ertürk, A.E.B., Şeker, D.Z. and Öztürk, I. 2013. 'Ottoman period water structures and water-related architecture: examples in Safranbolu, Turkey', *Water Science and Technology Water Supply* 13.3, 743–52.

España-Chamorro, S. 2021. 'The procurator Campaniae and the "Lands of Capua" on Crete', *BSA* 116, 377–97.

Evans, A.J. 1899–1900. 'Knossos. Summary report of the excavations in 1900: vol. 1. The Palace', *BSA* 6, 3–70.

Evans, A.J. 1902–3. 'The Palace of Knossos', *BSA* 9, 1–153.

Evans, A.J. 1903–4. 'The Palace of Knossos', *BSA* 10, 1–62.

Evans, A.J. 1928. *The Palace of Minos: A Comparative Account of the Successive Stages of the Early Cretan Civilization as Illustrated by the Discoveries at Knossos*, vol. 2 (London).

Evans, A.J. 1935a. *The Palace of Minos: A Comparative Account of the Successive Stages of the Early Cretan Civilization as Illustrated by the Discoveries at Knossos*, vol. 4.1 (London).

Evans, A. 1935b. 'Inexhaustible Crete: discovery of Villa Dionysos', *The Times* [newspaper], 29 July, 15.

Fabre, G., Fiches, J.L., Leveau, P. and Paillet, J.L. 1992. *The Pont du Gard. Water and the Roman Town* (Paris).

Fabre, G., Fiches, J.L. and Paillet, J.L. 2000. *L'Aqueduc de Nîmes et le Pont du Gard. Archéologie, géosystème, histoire* (CNRS Editions, CRA Monographies Hors Série; Paris).

Flouda, G. 2017. 'Archaeology in the war zone: August Schorgendorfer and the Kunstschutz on Crete during World War II', *BSA* 112, 341–77.

Forster, G. 2009. 'Roman Knossos: the pottery in context. A presentation of ceramic evidence provided by the Knossos 2000 Project (1993–95)' (unpublished PhD thesis, University of Birmingham).

Fortini Brown, P. 2021. 'The other Francesco Morosini', *Artibus et Historiae: An Art Anthology* 84, 149–94.

Galanaki, K., Grigoropoulos, D., Kastanakis, A., Mandalaki, S., Papadaki, C. and Triantafyllidi, I. 2006. 'The management of water resources in Chersonissos, Crete, Greece, during the Roman Period', in A.N. Angelakis and D. Koutsoyiannis (eds), *1st IWA International Symposium on Water and Wastewater Technologies in Ancient Civilizations* (Heraklion), 265–70.

Gerola, G. 1905. *Monumenti Veneti dell' Isola di Creta*, vol. 1 (Venice).

Gerola, G. 1932–40. *Monumenti Veneti dell' Isola di Creta*, vol. 4 (Venice).

Giorgi, E. 2010. 'Il cantiere di un acquedotto. Il caso di Gortina (Creta)', in S. Camporeale, H. Dessales and A. Pizzo (eds), *Archeologia della Costruzione II. I cantieri edili dell'Italia e delle Province orientali* (Anejos de Archivo Español de Arqueologia 57; Madrid and Mérida), 419–36.

Giorgi, E. 2016. *Archeologia dell'Acqua a Gortina di Creta in età Protobizantina* (Limina/Limites: Archaeologies, Histories, Islands and Borders in the Mediterranean 5; Oxford).

Hodge, A.T. 1983. 'Siphons in Roman aqueducts', *PBSR* 51, 174–221.

Hodge, A.T. 1992. *Roman Aqueducts and Water Supply* (London).

Hoffmann, G., Kummer, S., Márquez, R. and Valdivia Manchego, M. 2019. 'The Roman Eifel aqueduct: archaeoseismological evidence for neotectonic movement at the transition of the Eifel to the Lower Rhine Embayment', *International Journal of Earth Sciences* 108, 2349–60.

Hogarth, D.G. 1899–1900a. 'Knossos. Summary report of the excavations in 1900: II. Early town and cemeteries', *BSA* 6, 70–85.

Hogarth, D.G. 1899–1900b. 'Knossos. Summary report of the excavations in 1900: IV. A Latin inscription', *BSA* 6, 92–3.

Hood, M.S.F. and Smyth, D. 1981. *Archaeological Survey of the Knossos Area* (*BSA* Supp. Vol. 14; London).

Hutchinson, R.W. 1938–40. *KNO 68 Archaeological Daybook for 1938–1940* (available online <https://digital.bsa.ac.uk/results.php?creator-irn=744andirn=55858> accessed August 2022).

Jansen, G. 2019. 'Introduction. A lively place: workers and labourers are building the Değirmendere aqueduct', in G. Wiplinger (ed.), *Der Degirmendere Aquädukt von Ephesos* (*BABESCH* Supp. Vol. 36; Leiden), 367–402.

Karanastasi, P. 2016. 'Roman imperial sculpture from Crete: a reappraisal', in J.E. Frances and A. Kouremenos (eds), *Roman Crete. New Perspectives* (Oxford), 101–18.

Kelly, A.M. 2004. 'The Roman aqueducts and bathhouses of Crete', 3 vols (unpublished PhD thesis, Trinity College Dublin) (available online <www.tara.tcd.ie/handle/2262/77829> accessed January 2023).

Kelly, A.M. 2004–5. 'In search of a Roman bathhouse in the Malia area', *BCH* 128–9, 607–27.

Kelly, A.M. 2006. 'The impact of aqueduct construction on the demographic patterns of Crete', in G. Wiplinger (ed.), *Cura Aquarum in Ephesus*, vol. 2 (Vienna), 315–22.

Kelly, A.M. 2013. 'Roman bathhouses on Crete as indicators of cultural transition: the dynamics of Roman influence', in A. Gardner, E. Herring and K. Lomas (eds), *Creating Ethnicities and Identities in the Roman World* (*BICS* Supp. Vol. 120; London), 129–64.

Kelly, A.M. 2018. 'A Roman aqueduct through the Cretan highlands – securing the water supply for elevated Lyttos', in G.A. Aristodemou and Th.P. Tassios (eds), *Great Waterworks in Roman Greece. Aqueducts and Monumental Fountain Structures: Function in Context* (Roman Archaeology 35; Oxford), 147–69.

Kelly, A.M. 2022. 'The enduring springs of the Venetian aqueduct of Candia (Iraklio) Crete; from a Roman stone pipeline to Morosini's Venetian bridge', *Schriftenreihe der Frontinus-Gesellschaft* 33, 117–58.

Kelly, A.M. forthcoming. 'A Roman villa at Myrtos – the 1973 season', in conference proceedings of Ε΄ Παγκρήτια Επιστημονική Συνάντηση Αρχαιολογικό Έργο στην Κρήτη, 21–24 November 2019.

Kessener, P. 2022. 'Roman water transport: pressure lines', *Water* 14.1, 1–67.

Kotsonas, A. 2016. 'Greek and Roman Knossos: the pioneering investigations of Minos Kalokairinos', *BSA* 111, 299–324.

Lalonde, B. 2019. 'The water challenge', *Horizons: Journal of International Relations and Sustainable Development* 13, 184–93.

Laporte, J.P. 1996. 'Notes sur l'aqueduc de Saldae (Bougie)', in M. Khanoussi, P. Ruggeri and C. Vismara (eds), *Atti dell'XI convegno di studio, Cartagine, 15–18 dicembre 1994* (Ozieri), 711–62.

Leigh, S. 2018. 'The monumental fountain in the Athenian Agora: reconstruction and interpretation', in G.A. Aristodemou and Th.P. Tassios (eds), *Great Waterworks in Roman Greece. Aqueducts and Monumental Fountain Structures: Function in Context* (Roman Archaeology 35; Oxford), 218–34.

Leveau, P. 1991. 'Research on Roman aqueducts in the past ten years', in T. Hodge (ed.), *Future Currents in Aqueduct Studies* (Leeds), 149–62.

Leveau, P. 2001. 'Aqueduct building: financing and costs', in D.R. Blackman and A.T. Hodge (eds), *Frontinus Legacy: Essays on Frontinus' de aquis urbis Romae* (Ann Arbor, MI), 85–101.

Lewis, M. 1999. 'Vitruvius and Greek aqueducts', *PBSR* 67, 145–72.

Lewis, M. 2001. *Surveying Instruments of Greece and Rome* (Cambridge).

Lolos, Y.A. 1997. 'The Hadrianic aqueduct of Corinth', *Hesperia* 66, 271–314.

Mackridge, P. (ed.) 2020. *The Crete of R.M. Dawkins (1903–1919)* (Oxford) (available online <https://dawkinscrete.mml.ox.ac.uk> accessed June 2022).

Manoledakis, M. 2018. 'The water supply of Roman Thessaloniki', in G.A. Aristodemou and Th.P. Tassios (eds), *Great Waterworks in Roman Greece. Aqueducts and Monumental Fountain Structures:*

Function in Context (Roman Archaeology 35; Oxford), 50–69.
Markoulaki, S. 2000. "Κέντρο Υγείας", *ArchDelt* 55, 1029.
Markoulaki, S. 2009. "«Αριστοκρατικές» Αστικές Επαύλεις στην Ελληνορωμαϊκή Κίσαμο", in Ch. Loukos, V. Xifaras and K. Pateraki (eds), *Ubi Dubium Ibi Libertas. Τιμητικός Τόμος για τον Καθηγητή Νικόλα Φαράκλα* (Rethymno), 337–80.
Markoulaki, S. and Christodoulakos, Y. 2018. "Η Αρχαία Πολυρρήνια και το σύστημα ύδρευσής της", *Κρητική Εστία* 15, 75–140.
Marzano, A. 2007. *Roman Villas in Central Italy: A Social and Economic History* (Leiden and Boston, MA).
Morgan, C. 2009. 'Federico Halbherr and Knossos', *ASAtene* 87, 43–67.
Nixon, C.E.V. and Saylor Rodgers, B. 1994. *In Praise of Later Roman Emperors. The Panegyrici Latini* (Berkeley, CA).
O'Connor, C. 1993. *Roman Bridges* (Cambridge).
Ohlig, C. 1996. 'Anmerkungen zum Funktionsmodell des Castellum Aquae im antiken Pompeji', in N. de Hann and G. Jansen (eds), *Cura Aquarum in Campania* (*BABESCH* Supp. Vol. 4; Leiden), 19–27.
Oikonomakis, N.E. 1986. "Το Υδραγωγείο της Χερσόνισου", *Lyktos* 2, 50–98.
Panagiotaki, M. 2004. 'Knossos and Evans: buying Kephala', in G. Cadogan, E. Hatzaki and A. Vasilakis (eds), *Knossos: Palace, City, State* (*BSA* Studies 12), 513–36.
Papadaki, Chr., Triantafyllidi, I. and Grigoropoulos, D. 2010. "Λουτρικό συγκρότημα στον Λιμένα Χερσονήσου: σωστική ανασκαφή", *Αρχαιολογία και Τέχνες* 115, 35–40.
Pashley, R. 1837. *Travels in Crete I and II* (London).
Paton, S. 1998. 'The Villa Dionysos and its predecessors', in W.G. Cavanagh and M. Curtis (eds), *Post-Minoan Crete: The 2nd Colloquium* (*BSA* Studies 2; London), 123–8.
Paton, S. 2004a. 'The Villa Dionysos at Knossos: Recent Work', in A. Di Vita, M. LivaDioti and I. Simiakaki (eds), *Creta romana e protobizantina: atti del congresso internazionale organizzato dalla Scuola Archeologica Italiana di Atene (Iraklion, 23–30 settembre 2000)*, vol. 2 (Padua), 281–5.
Paton, S. 2004b. 'Knossos: an imperial renaissance', in G. Cadogan, E. Hatzaki and A. Vasilakis (eds), *Knossos: Palace, City, State* (*BSA* Studies 12), 451–5.
Paton, S. 2022. 'The so-called Villa Dionysos at Knossos', *BSA* 117, 1–41.
Popham, M.R. and Sackett, L.H. 1972–3. 'The Unexplored Mansion at Knossos: a preliminary report on the excavations from 1967 to 1972', *AR* 19, 50–71.
Putnam, M.C.J. 2019. 'Statius Silvae 1.3: a stream and two villas', *Illinois Classical Studies* 44.1, 66–100.
Rashed, Z.E. 1978. *Η Κρήτη υπό την Αιγυπτιακήν Εξουσίαν, 1830–1840*, trans. from Arabic by Eug. Michailides and ed. by St. Spanakis (Heraklion).
Raulin, V. 1867. *Description physique de l'ile de Crète*, vol. 1 (Paris).
Rethemiotakis, G. and Warren, P.M. 2014. *Knossos: A Middle Minoan LII Building in Bougadha Metochi* (*BSA* Studies 23).
Rigsby, K.J. 1976. 'Cnossos and Capua', *Transactions and Proceedings of the American Philosophical Association* 106, 313–30.
Roberts, N. 1979. 'The location and environment of Knossos', *BSA* 74, 231–41.
Roby, C. 2018. 'Geometer, in a landscape: embodied mathematics in Hero's *Dioptra*', in M. Sialaros (ed.), *Revolutions and Continuity in Greek Mathematics* (Berlin), 67–88.
Rogers, D.K. 2018. 'Shifting tides: approaches to the public water-displays of Roman Greece', in G.A. Aristodemou and Th.P. Tassios (eds), *Great Waterworks in Roman Greece. Aqueducts and Monumental Fountain Structures: Function in Context* (Roman Archaeology 35; Oxford), 173–92.
Sackett, L.H., Branigan, K., Callaghan, P.J., Catling, H.W., Catling, E.A., Coldstream, J.N., Higgins, R.A., Popham, M.R., Price, J., Price, M.J., Waywell, G.B. et al. 1992. *From Greek City to Roman Colony: Excavations at the Unexplored Mansion II* (*BSA* Supp. Vol. 21; London).
Sarris, A., Papadopoulos, N., Cantoro, G., Agapiou, A., Déderix, S., Tsigonaki, C. and Devolder, M. 2015. 'New technologies for capturing the dynamics of cultural landscapes', *Αρχαιολογικό Έργο Κρήτης* 3A, 689–99.
Schram, W. 2020. 'Roman aqueducts' (available online <www.romanaqueducts.info/technicalintro/costs.htm> accessed July 2022).
Spanakis, St.G. 1950. *Francesco Moresini, Relazione presentata nell'eccentissimo Consiglio, MDCXXIX* (Heraklion).
Spanakis, St.G. 1981. *Η ύδρευση του Ηρακλείου 828–1939* (Heraklion).
Spanakis, St.G. 1990. *Το Ηράκλειο στο Πέρασμα των Αιώνων* (Heraklion).
Spyropoulos, Y. 2018. 'Running water for the officials, rainwater for the poor: symbolic use and control of water in early modern Ottoman Crete', *Water History* 10, 103–12.
Stavrinidis, N. 1969. "Οι φιλανθρωπικές κρήνες του Μεγάλου Κάστρου (τα Σεμπίλια)", *Patris* [newspaper] 2–18 November.
Stavrinidis, N. 1984. *Μεταφράσεις Τουρκικών ιστορικών εγγράφων αφορώντων εις την ιστορίαν της Κρήτης*, vol. 4 (Heraklion).
Stavrinidis, N. 1985. *Μεταφράσεις Τουρκικών ιστορικών εγγράφων αφορώντων εις την ιστορίαν της Κρήτης*, vol. 5 (Heraklion).
Stenton, E.C. and Coulton, J.J. 1986. 'Oinoanda: the water supply and aqueduct', *AnatSt* 36, 15–59.
Steriotou, I. 1992.*Οι βενετικές οχυρώσεις του Ρεθύμνου (1540–1646). Συμβολή στη φρουριακή αρχιτεκτονική του 16ου και του 17ου αιώνα*, vol. 1 (Athens).
Stillman, W.J. 1868. Cretan Days III. *The Atlantic Monthly* [magazine], March, 326–32.
Strataridaki, A.I., Chalkiadakis, E.G. and Gigourtakis, N.M. 2009. 'The history of the Fundana spring aqueduct and its significance for the water supply of Heraklion city (Crete) through the ages', paper delivered at IWA Speciality Conference: 2nd International Symposium, 28–30 May, Bari, Italy, 1–8 (available online <www.academia.edu/1522678/The_history_of_the_Fundana_spring_aqueduct_and_its_significance_for_the_water_supply_of_Heraklion_city_Crete_through_the_ages> accessed January 2023).
Sweetman, R. 2003. 'The Roman mosaics of the Knossos valley', *BSA* 98, 517–47.
Sweetman, R. 2007. 'Roman Knossos: the nature of a globalized city', *AJA* 111.1, 61–81.

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

Sweetman, R. 2013. *The Mosaics of Roman Crete. Art, Archaeology and Social Change* (Cambridge).
Sweetman, R. and Grigoropoulos, D. 2010. 'Roman Knossos: discovering the city through the evidence of rescue excavations', *BSA* 105, 339–79.
Taramelli, A. 1902. 'Cretan expedition. Gortyna', *AJA* 6, 101–65.
Themelis, P.G. 1994–6. "Ελεύθερνα", *Κρητική Εστία* 5, 267–83.
Themelis, P.G. 2002. *Αρχαία Ελεύθερνα. Ανατολικός Τομέας* (Athens).
Themos, A.A. 1996–7. "Τὸ ρωμαϊκὸ Ὑδραγωγεῖο τοῦ Γυθείου, μία πρώτη ἐπανεξέταση τῶν στοιχείων", in *Πρακτικά του Ε' Διεθνούς Συνεδρίου Πελοποννησιακών Σπουδών* (Athens), 400–9.
Thenon, L. 1867. 'Polyrrhénie. Fragments d'une description de l'île de Crète', *RA* 15(I), 416–27.
Thomas, R. and Wilson, A. 1994. 'Water supply for Roman farms in Latium and south Etruria', *PBSR* 62, 139–96.
Tomlinson, R.A. 1995–6. 'Archaeology in Greece', *AR* 42, 1–47.
Trainor, C.P. 2019. 'Polis, colony and beyond: urban Knossos from Archaic to Late Antique times. Papers from a workshop at the 12th International Congress of Cretan Studies, Heraklion, 22 September, 2016', in C. Mitsotaki, L. Tzedaki-Apostolaki and S. Giannadaki (eds), *Proceedings of the 12th International Congress of Cretan Studies. Heraklion: Society of Cretan Historical Studies* (Heraklion), 1–15 (available online <https://12iccs.proceedings.gr/en/proceedings/category/39/35/814> accessed January 2023).
Vitti, P. 2016. *Building Roman Greece. Innovation in Vaulted Construction in the Peloponnese* (*StArch* 206; Rome).
Voudouris, K.S., Christodoulakos, Y., Steiakakis, E. and Angelakis, A.N. 2013. 'Hydrogeological characteristics of Hellenic aqueducts – like qanats', *Water* 5.3, 1326–45.
Wardle, K. 1998. "Πρόγραμμα «Κνωσός 2000»", *Η Καθημερινή. Επτα Ημερες* ΚΓ', 46–8.
Wardle, K. 2000. 'Knossos 2000' (available online <https://artsweb.cal.bham.ac.uk/aha/kaw/Knossos/INDEXknos.htm> accessed January 2023).
Warren, P. 1987–8. 'Knossos: Stratigraphic Museum excavations, 1978–82, Part IV', *AR* 34, 86–104.
Whitelaw, T., Bredaki, M. and Vasilakis, A. 2017. 'The Knossos Urban Landscape Project. Report on the 2017 study season', British School at Athens Report (available online <www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwj605T5_N_8AhVTTEEAHeuRByUQFnoECCQQAQ&url=https%3A%2F%2Fcanvas.brown.edu%2Fcourses%2F1072246%2Ffiles%2F61170104%2Fdownload%3Fwrap%3D1&usg=AOvVaw2IYGdgwfT6iRWMNI125VgT> accessed January 2023).
Whitelaw, T., Bredaki, M. and Vasilakis, A. 2019a. 'Long-term urban dynamics at Knossos: the Knossos Urban Landscape Project, 2005–16', in C. Mitsotaki, L. Tzedaki-Apostolaki and S. Giannadaki (eds), *Proceedings of the 12th International Congress of Cretan Studies. Heraklion: Society of Cretan Historical Studies* (Heraklion), 1–16 (available online <https://12iccs.proceedings.gr/en/proceedings/category/39/35/796> accessed January 2023).
Whitelaw, T., Bredaki, M. and Vasilakis, A. 2019b. 'The long-term dynamics of Knossos in context', in C. Mitsotaki, L. Tzedaki-Apostolaki and S. Giannadaki (eds), *Proceedings of the 12th International Congress of Cretan Studies. Heraklion: Society of Cretan Historical Studies* (Heraklion), 1–18 (available online <https://12iccs.proceedings.gr/en/proceedings/category/39/35/816> accessed January 2023).
WHO and UNICEF 2000. 'Global water supply and sanitation assessment 2000 report' (available online <www.who.int/publications/i/item/9241562021> accessed 18 August 2022).
Wiplinger G. 2019. 'Die Abschnitte und Einzelbauwerke von der Quelle in die Stadt', in G. Wiplinger (ed.), *Der Degirmendere Aquädukt von Ephesos* (*BABESCH* Supp. Vol. 36; Leiden), 55–339.
Zachos, K.L. and Leontaris, L. 2018. 'The aqueduct of Actian Nicopolis', in G.A. Aristodemou and Th.P. Tassios (eds), *Great Waterworks in Roman Greece. Aqueducts and Monumental Fountain Structures: Function in Context* (Roman Archaeology 35; Oxford), 26–48.

Το ρωμαϊκό υδραγωγείο της Κνωσού, ένα πρότυπο για το σχεδιασμό υδραγωγείων του δέκατου ένατου αιώνα

Στο άρθρο αυτό παρουσιάζουμε τα ευρήματα από μια αυτοψία πεδίου του υδραγωγείου της Κνωσού κατά το 2019. Μια βασική συμβολή στην έρευνα πεδίου ήταν η αρχιτεκτονική ταύτιση του ρωμαϊκού αγωγού υποκείμενου του τοίχους του Οθωμανικού-Αιγυπτιακού υδραγωγείου του 19ου αιώνα που εφοδίαζε το Ηράκλειο. Ενώ η επανάχρηση του Ρωμαϊκού υδραγωγείου κατά τον 19ο αιώνα ήταν γνωστή από ιστορικές αναφορές, η κατασκευαστική επικάλυψη δεν είχε ποτέ μέχρι τώρα ταυτιστεί στο πεδίο ή τεκμηριωθεί αρχαιολογικά. Καταγράψαμε τον ρωμαϊκό αγωγό που ήταν επενδυμένος με opus signinum και διέτρεχε κατά μήκος της βάσης του τοίχου του υδραγωγείου του 19ου αιώνα ανάμεσα στην Φουντάνα και τη Σπηλιά. Μέσω αυτής της κατανόησης στο πεδίο, μπορέσαμε να καθιερώσουμε διαγνωστικούς τύπους τοιχοποιίας και για τις δύο περιόδους. Η αρχιτεκτονική μας διάκριση ανάμεσα στα υπερκείμενα υδραγωγεία μάς επέτρεψε να ενσωματώσουμε προηγουμένως αποαρθρωμένα στοιχεία του υστερότερου συστήματος, όπως η επαναχρησιμοποιημένη ρωμαϊκή σήραγγα στο Σκαλάνι και η γέφυρα του 19 ου αιώνα στη Σπηλιά, μέσα σε μια ολοκληρωμένη

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press

παροχή νερού για το Ηράκλειο. Πλησιάζοντας την Κνωσό από την Σπηλιά, μπορέσαμε επίσης να ταυτίσουμε το σημείο όπου το Ενετικό υδραγωγείο που εφοδίαζε το Ηράκλειο συνέκλινε με το ρωμαϊκό σύστημα. Συνεπώς, η έρευνα πεδίου του 2019 όχι μόνο χαρτογράφησε το μήκος του ρωμαϊκού υδραγωγείου που εφοδίαζε την πόλη της Κνωσού αλλά και το τμήμα του του Οθωμανικού-Αιγυπτιακού υδραγωγείου του 19ου αιώνα του Ηρακλείου που κτίστηκε απευθείας πάνω του και μια μικρότερη έκταση του Ενετικού υδραγωγείου του Ηρακλείου που είτε διέτρεχε κατά μήκος του προηγούμενου, ή ήταν με τη σειρά του υποκείμενο στο σύστημα του 19ου αιώνα.

Μετάφραση: Στ. Ιερεμίας

https://doi.org/10.1017/S0068245422000156 Published online by Cambridge University Press