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The underground water systems of Ma'abarta—Flavia Neapolis, Israel

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Abstract

The Roman city Flavia Neapolis (Hebrew—Shechem; Arabic—Nablus) and its predecessor Hellenistic Ma'abarta, is a continuously active city, located close to Israel's water divide. The city prospered due to water abundance from local springs, associated with its setting along the natural outlet of the karstic aquifer of Mt. Gerizim, the holy site of the Samaritans. Complicated tunnel systems were constructed for water distribution and consumption during the Hellenistic-Roman periods. The subterranean systems of the major springs within the city, Ras el 'Ein, 'Ein Qaryun, and 'Ein Dafna, as well as the main tunnel running along the city include rock-hewn tunnels for groundwater collection, and masonry-built tunnels for the distribution of spring water to the city by gravitation, and for drainage. Architectural features and structures below the Roman city indicate that some tunnels had already been constructed during the preceding Hellenistic period. A potential cultic element of the urban hydrographic system can be inferred from the elaborate entrance structures of the large springs, Ras el 'Ein and 'Ein Qaryun, as well as from historic accounts. Documentary references to the subterranean water system indicate that its existence may date as far back as 2000 years ago.

KEYWORDS
Roman, aqueducts, 31 B.C.E. earthquake, barrel vaults, springs, water tunnels

1 | INTRODUCTION

The hydrogeology of Ma'abarta—Flavia Neapolis is unique among southern Levantine cities, based on documentary accounts as well as the archaeological record. The water systems discussed in this paper provide evidence of these ancient systems, currently unexposed and completely concealed underground. These subterranean systems preserve structural evidence that is singular within the contexts of ancient artificial cavities (e.g., Parise et al., 2013).

1.2 | Hydrogeology

The southern Levant is located at the desert border, and features a dry Mediterranean to arid climate. The ancient cities along the backbone of Israel's central mountain ridge such as Jerusalem (Fig. 1) commonly experienced water shortages, as springs across this elevated terrain are rare and typically small (e.g., Frumkin, 1999; Mazar, 2002), typical of the situation on most karst areas (Parise & Sammarco, 2015). As most cities had no large springs within their urban domains, varied efforts were undertaken to overcome water shortages. For example, Jerusalem's extensive population during the Hellenistic-Roman periods exceeded the city's supply of water derived from a single, low-elevation spring (Benami-Amiel, Grodek, & Frumkin, 2010). This restriction necessitated implementation of various strategies to maximize water storage and distribution. Chief among these were runoff harvesting into cisterns and large reservoirs, as well as construction of long aqueducts and tunnels that mobilized and diverted water from remote springs (Amit & Gibson, 2014). Similar strategies were applied in Sebaste (Frumkin, 2002; Fig. 1b), a city without any springs within its boundaries. Low-elevation cities, such as Akko—Ptolemais (Frankel, 2002), Caesarea (Porath, 2002), and Dor (Peleg, 2002; Fig. 1a), also lacked springs within their urban territories, but their low-altitude settings allowed for the diversion of large water supplies from regional sources and catchments. The aforementioned cities became increasingly dependent on water supply from distant sources when their populations increased during the Hellenistic-Roman periods.

Ma'abarta—Flavia Neapolis is a hydrogeological exception, as it contained large springs within the city and at locations less than 1 km from the city limits. The city's unique hydrogeological setting is partially a product of its location within a deep transverse valley that breaches the central synclinal divide ridge, between Mt. Gerizim to the south and Mt. Ebal to the north (Fig. 2). The main recharge zone of the Ma'abarta—Neapolis springs is the elevated terrain of Mt. Gerizim.

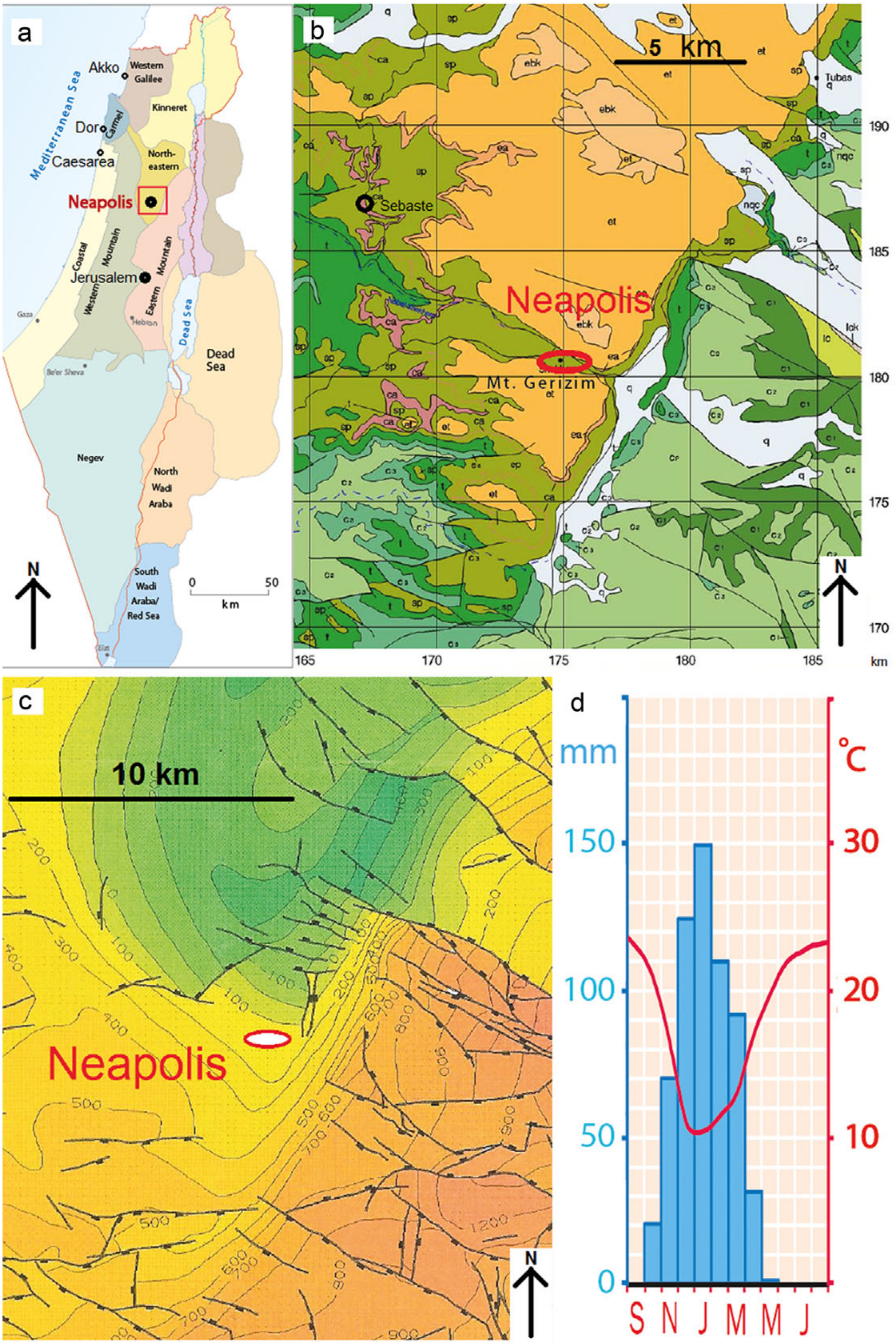

FIGURE 1 (a) Location map with main groundwater catchments of the region. (b) Geologic map of the research area (map area marked on a). The aquifer of Neapolis springs is within et = Eocene Timrat Formation cropping out on Mt. Gerizim, south of the city (courtesy Israel Geological Survey). Grid is 5 km. lck = lower Cretaceous; c1 = Albian—lower Cenomanian; c2 = middle Cenomanian; c3 = upper Cenomanian; t = Turonian; sp = Senonian-Paleocene; ca = Campanian; ea = lower Eocene; et = lower-middle Eocene; ebk = middle Eocene; nqc = Neogene-Quaternary; q = Quaternary. (c) Structural map (top Judea Group) of Neapolis region. Map area same as b (courtesy Israel Geophysical Institute). Thin lines are structural contours in meters relative to mean sea level. Thick lines are faults; teeth note downfaulted side. Note that Neapolis is located at the focal point of Mt. Gerizim dips. (d) Neapolis rainfall and temperature (Atlas of Israel) [Color figure can be viewed at wileyonlinelibrary.com]

FIGURE 2 The topographic setting of Neapolis-Shechem, between Mt Ebal and Mt. Gerizim, oblique Google Earth view from the NE. The synclinal aquifer of Mt. Gerizim is shown schematically. The main springs flow at the northern (right) edge of Mt. Gerizim [Color figure can be viewed at wileyonlinelibrary.com]

Structurally, this ridge is a syncline, demarcating the upstream edge of the northeastern mountain subaquifer, which is the most important Eocene aquifer in Israel (Cook, Roth, & Mimran, 1970) (Figs. 1c and 2). The limestone is underlain by Paleocene marls of the Mt. Scopus Group which forms an impervious aquiclude (Cook et al., 1970). The synclinal structure of the ridge plunges northward, such that groundwater converges from Mt. Gerizim northward, toward Neapolis (Figs. 1c and 2). The ridge is steeply entrenched by the Shechem valley, and Ma'abarta—Neapolis emerged at the foot of the steep slopes of Mt. Gerizim.

Rainfall infiltrates easily at the fracture-dissected and barren outcrops of the Eocene Timrat Formation limestone on the mountain (Fig. 1b). The formation is well-bedded, promoting subhorizontal water flow along bedding planes northward, along the dip of the syncline axis.

Mean annual rainfall at Gerizim—Neapolis area is 594 mm (Fig. 1d). Warm temperatures induce annual potential evaporation of 1600 mm (The New Atlas of Israel, 2011). Within this Mediterranean climate zone, rainfall totals are concentrated between November to April, while the summer is hot and dry. Only the larger rain storms between December to March provide sufficient water to replenish the aquifer (Sheffer et al., 2010). Ma'abarta—Flavia Neapolis spring discharges reflect this annual pattern, wherein late winter-spring flow substantially exceeds late summer-autumn discharge (Fig. 3). Waters within the studied spring complexes are supersaturated with respect to calcite, and undersaturated with respect to dolomite (Sabri, Merkel, & Tichomirowa, 2015). That trend is typical for the Eocene limestone aquifer. The main water solutes are derived from the limestone bedrock, and a secondary source is soil derived. Sr isotopes indicate that Ras el 'Ein has the lowest concentration of soil-derived solutes, 'Ein Qaryun is slightly more enriched in soil solutes, and 'Ein Dafna has the highest Sr isotopic values, indicating a higher concentration of soil-solutes content (e.g., Frumkin & Stein, 2004).

1.3 | History and archaeology

The Roman city Flavia Neapolis (henceforth: Neapolis) was founded by the Romans in 72–73 C.E., as indicated by the city coins (El-Fanni, 2007). The location was on the site of the Hellenistic town "Ma'abarta" (Flavius, Wars, 4:8:1) or at "Mamortha" (Pliny the Elder, V:14, p. 427) close to the Biblical city Shechem (Wright, 1965). Neapolis is well-documented from archaeology, coins, and historical records, but its predecessor Ma'abarta is only sparsely documented and still needs to be studied (Magen, 2009). While the population of Ma'abarta is unknown, Neapolis was a gentile city with a pagan temple during Roman times. A Christian population grew in number and was subsequently replaced by Moslems. Samaritan and Jewish minorities also played a role in the city's history.

Several historic records mention briefly the abundant water sources of Neapolis. Al-Muqaddasi (1994, p. 146) described the city around 985 C.E. as follows: "It lies in a valley shut in between two mountains…The town is paved and clean, with a stream of running water through it." The running water is mentioned also by other writers, such as Dimashki, and by Ibn Batutah (quoted in Le-Strange, 1965, pp. 513–514).

The medieval geographer Yaqut al-Hamawi, writing around 1225 C.E., noted that "Nabulus has much water, for it lies adjacent to a mountain, where the soil is stony" (quoted in Le-Strange, 1965, p. 512). This description is consistent with the karstic nature of Mt. Gerizim with its many springs, which still supply water to modern Nablus.

Geographers and travelers confirmed the abundance of flowing water in the city during the 19th century in art (e.g., Fig. 4), maps

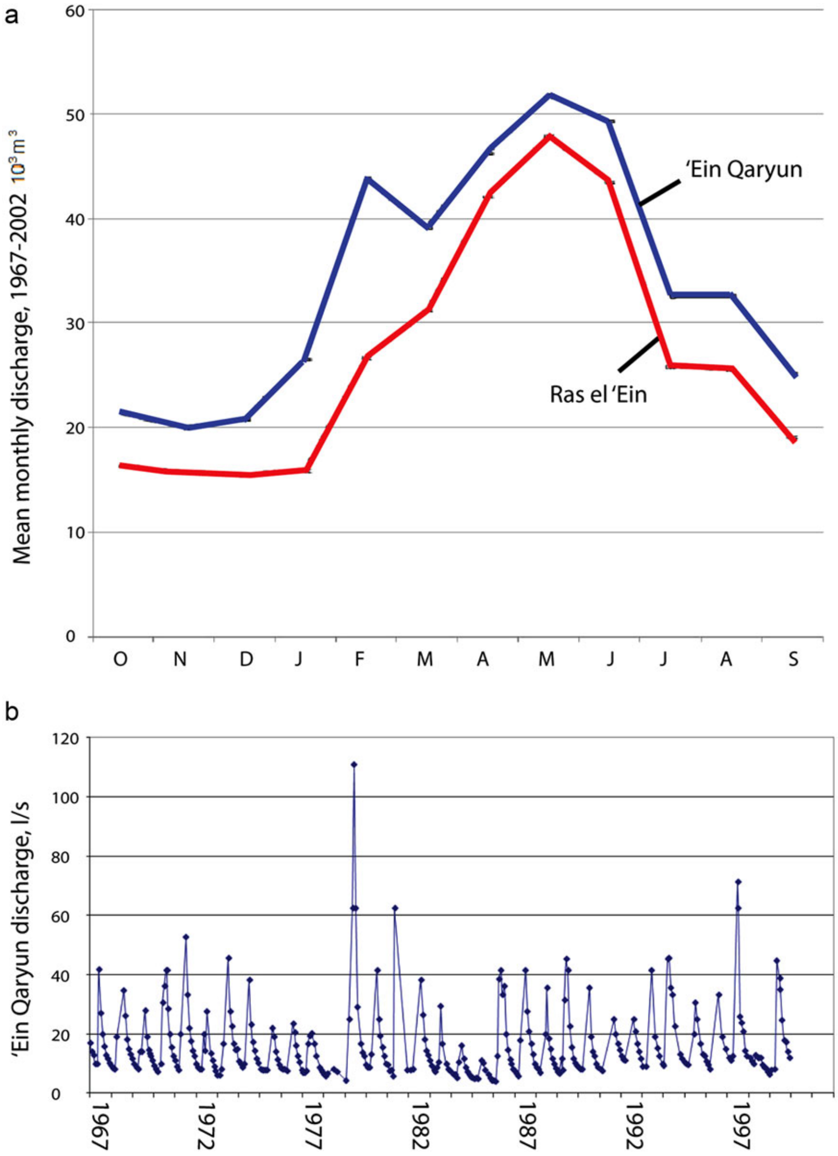

FIGURE 3 Discharge of the two major springs at Neapolis. (a) Mean monthly average of ’Ein Qaryun and Ras el ’Ein. (b) ’Ein Qaryun discharge 1967–2000 [Color figure can be viewed at wileyonlinelibrary.com]

(e.g., Fig. 5), and textual reports: 15 springs within the city walls were reported by Guérin (1874, vol. 4, p. 267), and 22 springs in the city’s neighborhood were mentioned by Conder and Kitchener (1882, vol. 2, p. 150). The present research demonstrated that some of these features are just secondary surface openings of shafts connected to the intricate underground water system. Three or four major springs within the city, reported in the 19th century by the travelers Wolcott and Buckingham, respectively (quoted in Ritter, 1866, pp. 302–303), appear to represent the number of springs active at that time.

Today the modern city and the old Kasbah at its heart hardly hint at the extent and configuration of the ancient water systems. These ancient subterranean water networks of Ma’abarta—Neapolis are difficult to reconstruct, partly because they have become part of the contemporary hydrographic network and water supply of the city of Nablus. The water fills reservoirs downstream of the springs, from where it is pumped to elevated reservoirs, and consequently distributed by gravitation to the city.

Recent archaeological studies, such as Bull (1965), El-Fanni (1999), and Magen (2009) briefly reference elements of the subterranean water systems in Neapolis, but these were not examined in detail, except for some of their entrance structures. Our previous study of the Samaria-Sebaste (Frumkin, 2002) network revealed that the excess of the composite high discharge of the Neapolis springs was mobilized and diverted to an aqueduct serving the city of Sebaste, 9 km NW of Neapolis.

The Muslim geographer Ahmad Al-Ya’qubi, in *Kitab al-Buldan* (*Book of the Countries*) around 891 C.E. (quoted in Le-Strange, 1965, p. 511) noted: “Under the town is an underground city hollowed out in the rocks.”

The present study is aimed to test the background of this statement, by documenting parts of the underground drainage, storage, and water

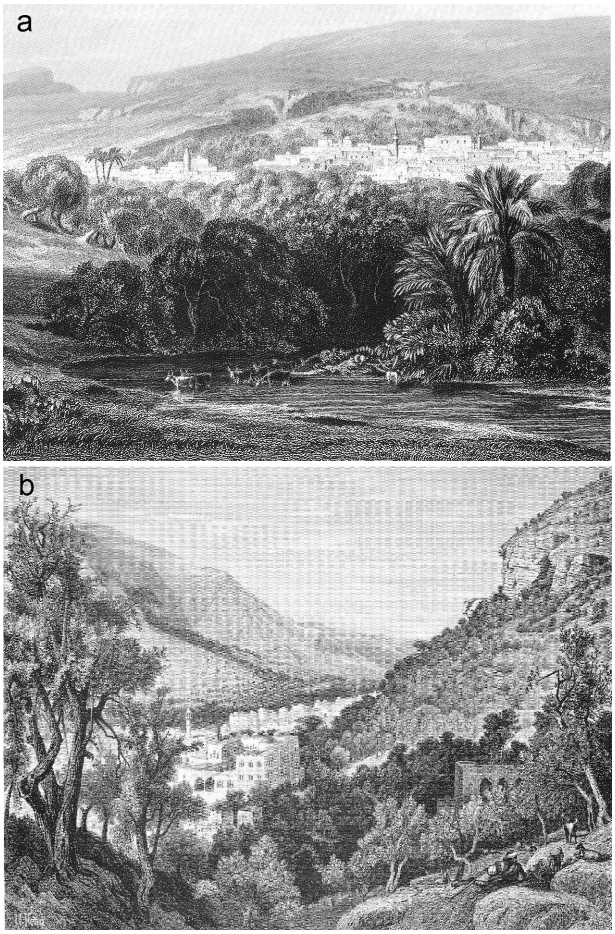

FIGURE 4 Copper etching drawings during the 19th century around Nablus, prior to major recent usage of water in the city. (a) Nahal Shechem west of Nablus. Note cows wading in a significant flow of water (Busch, 1863). (b) View from Ras el ’Ein to the city, at the foot of the steep slope of Mt. Gerizim (right). Note a water-operated flour mill at the lower right, which must have been using the water of Ras el ’Ein (Wilson, 1881).

supply network of this city for the first time. It might then be possible to decipher how the unique local hydrogeological setting was utilized for a sophisticated system supplying running water to the entire city, beyond the typical systems in place for most southern Levantine cities. The study also suggests a tentative chronological history and functional model for the water systems.

2 | METHODS

The underground water systems were accessible for study via certain entrances. Tunnels associated with these entrances were surveyed by tape, compass, and inclinometer. The term “tunnel” is used here to designate both bedrock-hewn elongated voids and covered channels, which, in the case of Ma’abarta—Neapolis are usually buried deeply underground. Such channels are used to convey water in soft sediments. In some cases covered channels are easier to construct relative to bedrock-hewn tunnels. The choice of construction mode was dictated by local geology, geomorphology, depth from the surface, and the distribution of above-ground buildings and ownership (Del Prete & Parise, 2013). Similar consideration was commonly taken into account for analogous water system construction and maintenance operations around the Mediterranean. Those concerns grew with time, especially during the Hellenistic and Roman periods when infrastructures were more complex (e.g., Castellani & Dragoni, 1991; Parise, 2012; Parise et al., 2015; Tassios, 2006; Voudouris, Christodoulakos, Steiakakis, & Angelakis, 2013).

The hydrogeology, morphology, archaeology, and architecture of the underground water systems were documented in the field and reviewed from available sources. Historical records were interpreted according to the relevant geographic–archaeological contexts, allowing for additional understanding of the water network. Written documentation and related accounts were used in cases where physical access was not feasible. In such cases, it is also possible, if not probable, that segments of the subterranean water system had been destroyed and blocked. Additionally, it is likely that some entrances remain unknown, given the changing population of the city and historic maintenance and construction events that either obliterated or masked evidence of earlier systems.

Summarily the studied subsystems were chosen on the basis of accessibility and importance. Not all elements of the antecedent systems could be reconstructed nor could the precise chronologies be determined. Similar problems are common for analogous studies elsewhere in the Levant and beyond. Subterranean drainage investigations require recognition of ancient features, some of which remain active in contemporary municipal water works (e.g., Hodge, 1992; Parise, 2012; Parise et al., 2015; Tassios, 2006). Thus the prospects for segregating ancient from contemporary features and functions provide complex challenges.

3 | RESULTS

The major water systems of Ma’abarta—Neapolis discussed herein are composed of the following underground systems: ’Ein Qaryun, Ras el ’Ein, and ’Ein Dafna, and the city’s so-called “main tunnel.” The spring flow outlets are currently confined to subterranean tunnels and are entirely hidden from surface observation. As noted, our understanding of the systemic function of the networks is key to comprehensive reconstructions. ’Ein Qaryun and Ras el ’Ein are the largest springs supplying water to the city (Figs. 6 and 7). ’Ein Dafna’s significance stems from its setting at the country’s drainage divide and its emergence as the primary stem at the key spring source. Another large spring, ’Ein Beit el-Ma, is not included in the present study, because its lower-lying location to the west of the city prevented its utility within the urban area. It is noted (Frumkin, 2002) that this spring provided source waters to the Samaria-Sebaste aqueduct and that it also served agricultural fields and flour mills.

Two primary excavation and engineering practices account for network propagation. The first is headward cutting of a tunnel in hard bedrock, using hammer and chisel, as indicated by hewing marks. The second is excavation of a trench in softer sediments, followed by construction of an ashlar tunnel that was subsequently covered by loose sediments.

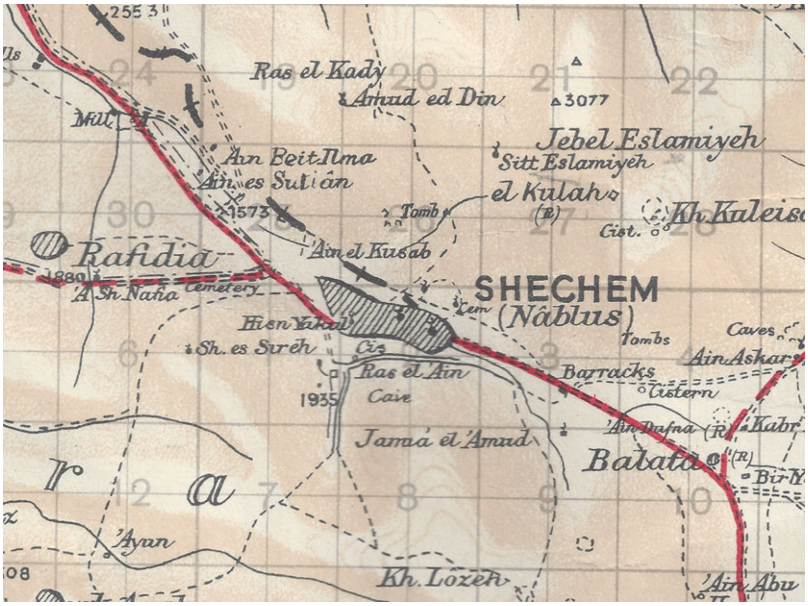

FIGURE 5 Map of Nablus in the 19th century (Conder & Kitchener, 1878). The city occupies approximately the central area of Neapolis. Note: Ras el 'Ain Cave and 'Ain Dafna ('Ain or 'Ein are similar). Grid is 0.4 km [Color figure can be viewed at wileyonlinelibrary.com]

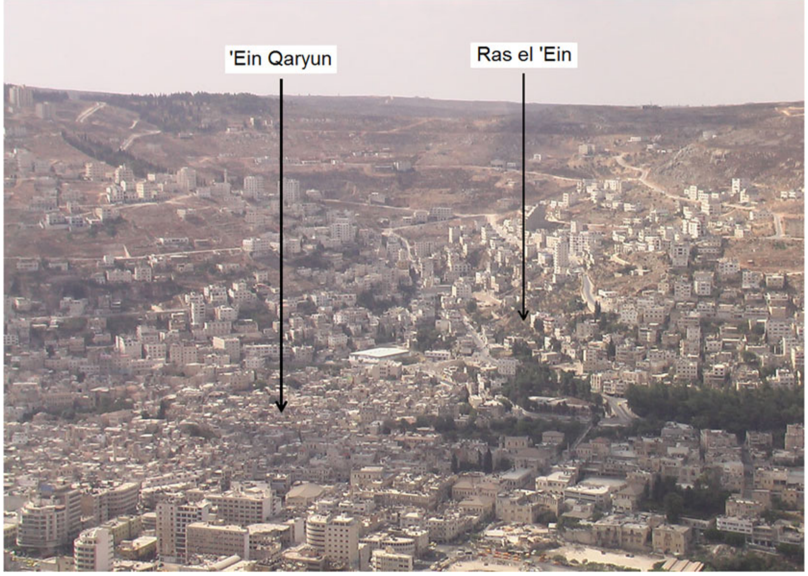

FIGURE 6 Nablus today with the two major springs at the foot of Mt. Gerizim, which serves as their recharge zone. View from the north. The old *Kasbah*, built on central Neapolis, surrounds 'Ein Qaryun. Photo: Boaz Langford [Color figure can be viewed at wileyonlinelibrary.com]

3.1 | 'Ein Qaryun

'Ein Qaryun is the largest spring within Neapolis city walls; it was probably the focal point of the initial settlement of Hellenistic Ma'abarta. It is a karstic spring flowing along the well-bedded Eocene limestone of the Timrat Formation, on the foot of Mt. Gerizim, 550 m above sea level (asl) (Figs. 6 and 7). The mean annual discharge is 386,000 m^3, with large seasonal fluctuations, as is common for such karstic springs (Fig. 3). Maximum spring season discharge is 110 l/s, while a minimum flow of ~5 l/s was recorded during the autumn of a dry year.

The spring flow line is currently accessed by 25 steps descending from a *Kasba* alley, near et-Tineh Mosque. The entrance is closely associated with an apsidal wall topped by a semidome, built of well-cut ashlars, and standing on a round raised platform. The structure was first reported by Clermont-Ganneau (1886, p. 315).

At the bottom of the steps the main spring tunnel (Fig. 8) is identifiable on the left (SE). The 14 m-long spring tunnel was hewn in well-bedded limestone with chert nodules, of the Eocene Timrat Formation. In the upstream direction the tunnel bifurcates to two narrow, inaccessible karstic conduits of few centimeters in diameter. The conduits formed along bedding plains, from which the water flows into the tunnel. Locally, the tunnel within widens, preserving the form of the original smooth natural karstic voids. Further downstream, the water flows underground through ancient built tunnel systems (below).

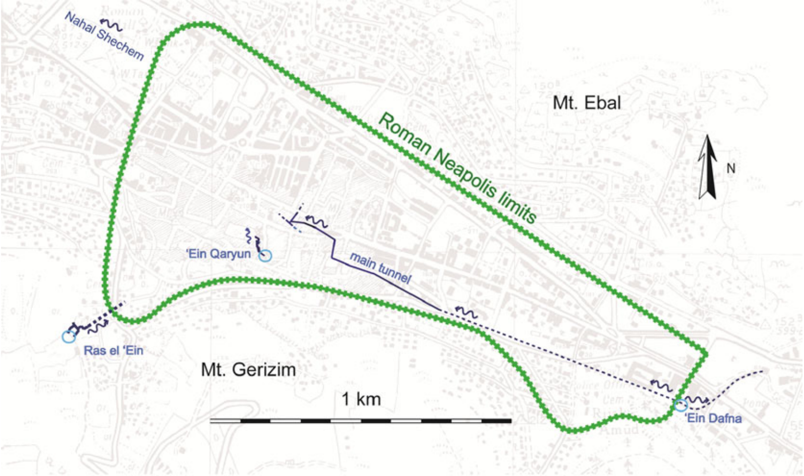

FIGURE 7 The studied underground systems superposed on a hypothetical plan of Neapolis (city walls after Magen, 2009) and 20th century city map (background). Wavy arrows indicate water flow direction. Circles indicate subsurface point of springs (bedrock-tunnel interface) [Color figure can be viewed at wileyonlinelibrary.com]

The downstream continuation of the spring tunnel, 1.2 m high and 0.6 m wide, is artificially built, but its upstream segment has a bedrock floor. Within a few meters the tunnel bifurcates to several passages, forming an intricate labyrinth-like system of masonry-built tunnels from various periods, generally sloping NNW, along the topographic grade (Fig. 6). The measured slope of the tunnels is on the order of 0 to 3°. The northern (downstream) segments expose ancient remains from classic periods, including many sherds, mosaic stones, a 1.6-m-long column, marble tablet, broken glass, and carved stone items. However, as is common to such systems, the presence of structural and even decorative remains does not necessarily date the tunnels and their periods of construction; segments and features may be related to later usage of the underground structures. Most tunnels have rectangular cross-sections, are built with roughly wrought stones, and are covered with flat stone slabs (Fig. 9). In places, recent renovations of the tunnels with concrete were observed. An exception is a 1.5-m-wide barrel-vaulted tunnel (semicylindrical in shape) built of well-wrought ashlars. Today this tunnel segment is blocked at both ends by later walls, limiting the accessible part of the barrel-vaulted tunnel to 8 m (Fig. 9a).

Some sections of the tunnel system were intermittently renovated including a relatively recent effort (Fig. 9b) that damaged ancient archaeological remains. The water is currently transported via an iron pipe ultimately emptying into a reservoir, from which it is distributed to consumers. Other tunnels seem not to be in use today, except the 14-m-long spring tunnel where water flow still spills out along the bedrock planes.

3.2 | Ras el 'Ein

Ras el 'Ein is one of the largest springs of Ma'abarta—Neapolis (Figs. 6 and 7). This highest spring of the city, 620 m asl, emerges from well-bedded Eocene limestone of the Timrat Formation at the southern slope of Mt. Gerizim, just above the ancient core of Ma'abarta—Neapolis. The elevated topographic setting allowed its water to be directed to any desired point within the city by gravity. The mean annual discharge is 308,000 m^3, subject to significant seasonal fluctuations, consistent with regional karstic spring discharge patterns (Fig. 3a). Maximal discharge is 30–40 l/s during the spring, while minimal flow is ~5 l/s during the autumn. The latter exemplifies the minimal water storage capacity of the aquifer.

Ras el 'Ein (رأس العين, Arabic for "Head of the Spring") is a common name for several important large springs in the Levant, for example, in Israel, Syria, and Jordan. Guérin (1874, vol. 4, p. 267) mentioned this spring following his 1870 visit, and reference to it is also made in the Palestine Exploration Fund map (Fig. 5) and associated text (Conder & Kitchener, 1882). However, Conder and Kitchener did not allude to the elaborate underground drainage system in their text (p. 150). A copper etching shows that the water of Ras el 'Ein was also mobilized for operating an old flour mill situated between the source waters and the city (Wilson, 1881; see Fig. 4b). The remains of additional mills are still dispersed along the Shechem valley, downstream, and to the west of the city.

Recent archaeological studies (e.g., El-Fanni, 1999) noted the impressive spring entrance structure (Figs. 10 and 11a) that provide access from the surface to the subterranean network. The original rectangular shaft-like structure is made of well-dressed ashlars with marginal drafting. It is preserved to a height of 15 courses, most of which are 0.6 m high, except for the first and the seventh, which attain heights of 0.75 and 0.5 m, respectively. A plastered, reinforced channel transported the spring water at the bottom of the entrance shaft structure from west to east. The water drains down from the entrance structure toward the city via a barrel-vaulted, ashlar-built tunnel (Figs. 10 and 11b). The individual blocks of stone are perfectly carved, and are tightly conjoined to one another. Currently, this tunnel is accessible for some 40 m downstream from the entrance structure, but its extended route toward the city was known in the 20th century (Magen, 2009). The water drains into two reservoirs about 150 m from the spring where the water feeds into contemporary consumer units.

The present investigations at Ras el 'Ein spring system concentrated on the upstream side of the entrance structure. Its first part

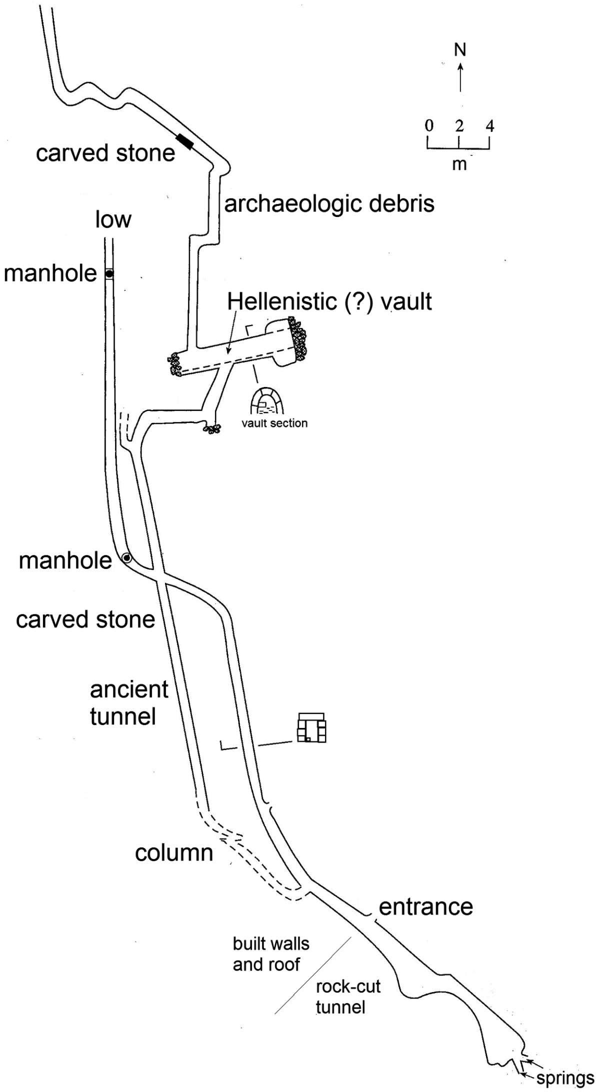

FIGURE 8 Plan of 'Ein Qaryun tunnel system, probable site of initial Hellenistic settlement of Ma'abarta, surveyed by the author. A short rock-cut tunnel drains the water from the spring point to masonry built tunnels, partly with a bedrock bottom

is a 4-m-long, well-constructed 1.3-m-wide tunnel (Figs. 10 and 11c). The vaulted roof of this short tunnel segment slopes from a height of 3.4 m at the entrance to 2.3 m at the innermost end, away from the entrance. This tunnel segment is built of well-dressed ashlars with marginal drafting and cemented by white mortar. A 30-cm-deep plastered channel is built into the floor of the tunnel.

From the end of the constructed tunnel segment, a subhorizontal, bedrock-hewn and segmented tunnel extends upstream to the mountain (Figs. 10 and 11d). This system forms one of the most intricate spring tunnels in Israel. The objectives here were to concentrate and increase water flow (Yechezkel & Frumkin, 2016). The bedrock tunnel was hewn mainly along bedding plains, fractures, and karstic voids that originally bound and guided stream flow. Chert nodules are observed along the tunnel within the limestone bedrock of the Eocene Timrat Formation. The cross-section is classically rectangular, making use of the bedded limestone for the commonly flat, bed-constrained ceiling (Fig. 11d). Occasionally the original karstic morphology was observed, with smoothly rounded walls and small, inaccessible side passages. The bedrock tunnel is mostly less than 1 m high. The tunnel direction diverges in concert with various fracture and karstic void orientations. Beyond the downstream 36 m segment of the hewn tunnel, it bifurcates to two main branches, in opposite directions along a single NW-SE trending fracture. Farther upstream, both branches turn to the southwest. Naturally karstified voids are increasingly visible at the upstream reaches of both passages, particularly where small side passages are observed. The southern passage terminates as water discharges from a tight inaccessible natural conduit. The northern passage has more side passages, with three inlet points, where water springs drain into the main passage. The depth of the flowing water is usually only a few centimeters, but during the rainy season of 2015 the water level was observed to rise along the system, rendering the tunnels barely accessible (Z. Erlich, personal communication, 2015). The slope of the hewn tunnels ranges between 1 to 5°. All the water drains underground through the ancient tunnel systems and modern pipe running at the bottom of the hewn and built tunnels.

The Ras el 'Ein water system is well-preserved. Today the system is still in use for drinking, and the water in the downstream reaches flows through an iron pipe.

3.3 | 'Ein Dafna

'Ein Dafna is situated at Israel's water divide, close to the eastern limit of Neapolis. Here water could be directed by gravitation both eastward and westward (Fig. 7). The mean annual discharge is 103,000 m^3, with large seasonal fluctuations, from 1.5 to 11 l/s during autumn and spring, respectively.

A 13-m-deep vertical shaft extends from the surface, at the bottom of Mt. Gerizim, to the spring. Although bedrock is not presently exposed at the spring, the water probably emerges from a karstic void similar to that of the spring at Ras el 'Ein. The local water table in the Eocene aquifer is tens of meters below the surface, as evidenced by the water level in the nearby Jacob's Well. Currently spring water flows over a reach of several hundred meters, within a recently plastered tunnel that is rectangular in cross-section. The tunnel flow is initially to the east, and then breaks northward via a long arc (in plan view), emptying into a reservoir close to Tell Balatah (Biblical Shechem; Wright, 1965). The 19th century map (Conder & Kitchener 1882) depicted (Fig. 5) a line from 'Ein Dafna to the northeast, curving eastward, to the vicinity of Tell Balatah. That presentation may represent a water system, but the textual description of the spring (pp. 150–151) does not make reference to this feature.

Two blocked tunnel outlets from the spring to the north and west were recorded by our investigations. The western outlet was directed toward Neapolis, and could have been connected with the main tunnel running along the city's main artery (below).

An elaborate description of the underground water systems of 'Ein Dafna, albeit without graphic presentation, was given by Bull (1965, pp. 218–221). Indications are, however, that the two additional outlets from the spring to the north and west were also blocked during his exploration. Thus the eastern tunnel is apparently the only one that

FIGURE 9 'Ein Qaryun tunnels. (a) Barrel-vaulted tunnel, 1.5 m wide; the shelf on the right is a secondary water channel. Note the blocking wall at the rear. Photo: Boaz Langford. (b) Tunnel built of large ashlar masonry at the left, stone slabs roof, with minor recent mortar repairs. Tunnel width is 60 cm. Photo: Ze'ev H. Erlich (Zabo) [Color figure can be viewed at wileyonlinelibrary.com]

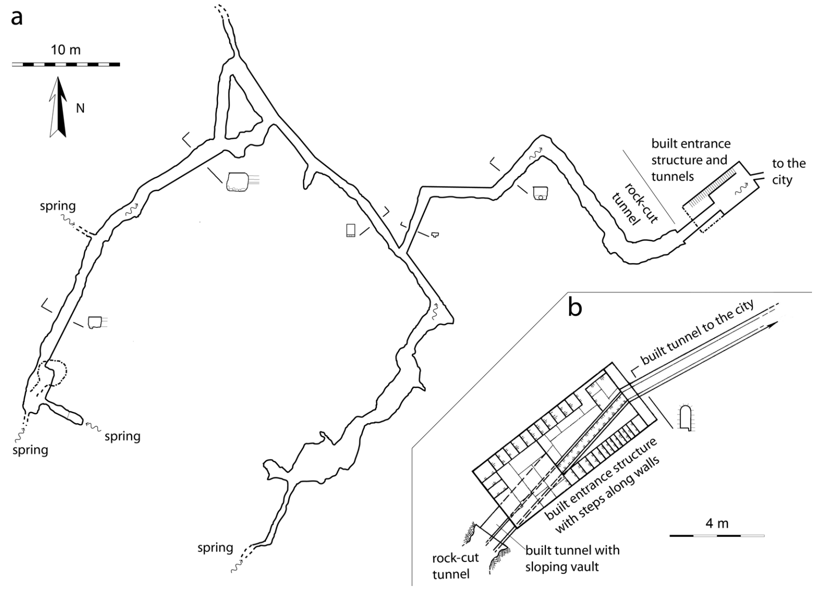

FIGURE 10 (a) Plan of the rock-cut spring tunnels and entrance structure of Ras el 'Ein surveyed by the author. Wavy arrows indicate water flow direction. (b) Entrance structure map enlarged (modified after El-Fanni, 1999; Magen, 2009)

has transported water over the last 50 years. Bull (1965, pp. 221–228) provided an elaborate description and plan of the 'Ein Balatah spring tunnel, to the east of 'Ein Dafna. 'Ein Balatah was not connected with the Ma'abarta—Neapolis water system, and is therefore not discussed here.

3.4 | The "main tunnel"

This longest tunnel of Ma'abarta—Neapolis ran partly under the *Decumanus*, the main street of Neapolis, in an approximate ESE-WNW direction (Fig. 7). We entered the tunnel through a Roman(?) staircase built of 56 steps that descended to a depth of 14 m below the *Decumanus* level. That feature was unearthed by El-Fanni (2007) beneath the Za'far el-Masri school during its construction. Lamps found along the staircase date to the 3rd to 4th century C.E., indicating that the tunnel was probably antecedent to that period. The tunnel is typically 60–70 cm wide, and 1.2–2 m high (Fig. 12), but has both higher and lower reaches. Cross-section area diminishes along the upstream reach due to accretion of calcite flowstone deposits, and at the downstream end due to renovations. Both impediments render the passageway less accessible. The tunnel is built of ashlar masonry, covered with slabs of stone (Fig. 12a), alternating with a barrel-vaulted roof of ashlars (Fig. 12b). These features indicate that the tunnel was initially excavated as an open channel, and subsequently finished with masonry roofing. This built roof is covered by a thick layer of debris upon which the *Decumanus* was subsequently constructed along the eastern part of the tunnel. The debris accumulated above the *Decumanus* was excavated by El-Fanni (2007). During the 1987 excavations poorly sorted natural debris, including cobbles and clay soil, together with collapsed archaeological material, were observed. These have collectively accumulated since the Roman period. The most probable source of this material is debris flows from the nearby steep northern slope of Mt. Gerizim.

The tunnel still contains water, flowing slowly along the graded slope of the Neapolis valley, from ESE to WSW. We performed a rough survey of the tunnel along 593 m of its course, 354 m upstream from the staircase, and 249 m downstream. The measured slope of the tunnel ranged from 0 to 3°.

FIGURE 11 Ras el 'Ein water system. Photos: Ze'ev H. Erlich (Zabo). (a) The bottom of the entrance structure and the outlet toward Neapolis with high water level (wet year, spring 2015). Most ashlar courses are 60 cm high. (b) The barrel-vaulted built tunnel leading from the entrance structure toward Neapolis. Width of tunnel 75 cm. (c) The sloping vaulted roof tunnel connecting the bedrock tunnel and the entrance structure. Tunnel is 1.3 m wide. (d) Rock-cut tunnel draining the karstic spring system. Bedrock is well-bedded Eocene limestone. Tunnel is ca. 2 m wide [Color figure can be viewed at wileyonlinelibrary.com]

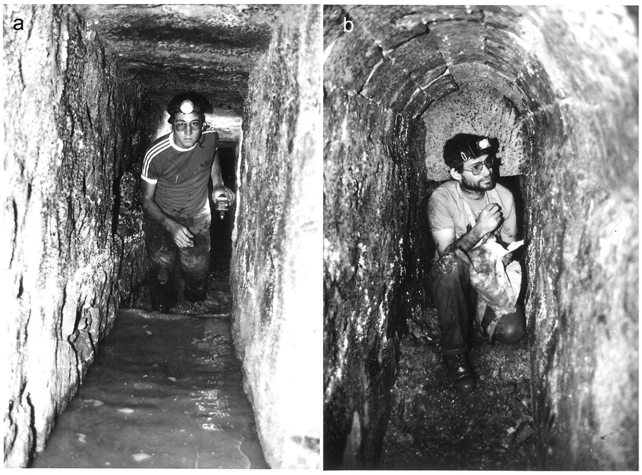

FIGURE 12 The main tunnel, built under the main street of Neapolis. Tunnel is ca. 70 cm wide. (a) Section covered with stone slabs. Photo: A. Frumkin. (b) Section with barrel-vaulted roof. Photo: Ofer Lavi

Several shafts connecting the main tunnel with the surface were observed, most prominently the Dullab shaft, which connects the tunnel to the modern street level, 16 m above. Most shafts were blocked at the top, with the exception of a single one, at the easternmost surveyed end, which was open during our study; the shaft was underlain by a pile of modern debris, partly blocking the tunnel.

Upstream from the staircase entrance the water is clear, and the tunnel is almost straight in plain view (Fig. 7). Some 354 m east of the tunnel staircase entrance the thickening flowstone deposits progressively inhibited access beyond the point of survey termination.

Downstream from the staircase entrance, the water becomes gradually polluted by sewage. At the Sha're Naser road (60 m reach), the tunnel turns sharply west to reach the Great Mosque, Jami' al-Kebir. Since that edifice is the major mosque in Nablus, it still bears signs of an earlier function as a major Byzantine-Crusader church (Conder & Kitchener, 1878, pp. 203, 208).

Over a length of 240 m the tunnel turns four times at a near right angle, while keeping the general flow direction to WNW. Two arterial tunnels join the main one, thus accommodating greater flow. Several phases of construction and repair are in evidence for this part of the tunnel, including a modern building stage that exposed concrete. Over the course of the survey the water level approached the ceiling, where, again, the field survey had to be halted.

Bull (1965, p. 221) apparently visited the same tunnel, having entered through a different point: "The 850 m long tunnel…appears to be of Roman construction and runs from a point near the prison and is part of that city's water system. The eastern opening of this tunnel could not be found."

Thus the tunnel is at least 600 m long according to our survey, extending 850 m per the Bull (1965) account. It probably carried water from 'Ein Dafna toward mid-Neapolis and further downstream along Nahal Shechem. The tunnel flows along the southern slope of Mt. Gerizim, not far from the southern wall of Neapolis.

A local inhabitant at 'Ein Beit el-Ma (Ain Beit Ilma, Fig. 5), west of Neapolis, informed us that during the 1940s he went along a high, impressive tunnel, from the vicinity of 'Ein Beit el-Ma upstream and extending to termination in the vicinity of Mt. Gerizim. This person noted that this tunnel segment was blocked in about 1965, an observation that could not be independently confirmed (A. Naji, personal communication, 1977). We did note the remains of several surface water channels in the vicinity of 'Ein Beit el-Ma. Some of these were clearly ancient, including an aqueduct that was traced over 15 km toward Sebaste (Frumkin, 2002). The main tunnel is still used as a drainage system, for the reach explored by our team.

4 | DISCUSSION

The unique situation of a southern Levantine city with surplus water provided a basis for a high standard of living, but that benefit was tempered by the need for water flow to be controlled and distributed appropriately. A carefully engineered network of spring water mobilization and conveyance was needed, not only for general water use, but also for regulating the flow of excessive water, and avoiding waste

TABLE 1 Architectural and hydrogeological components of the studied subsystems

Subsystem	Main Function	Subsequent Changes	Tunnel Type	Built Tunnel Form
Ein Qaryun	Spring	New built tunnels	Hewn and built	Rectangular + barrel vault
Ras el 'Ein	Spring	Almost none	Hewn and built	Barrel vault
Ein Dafna	Spring	Tunnel renovated	Built	Rectangular
Main tunnel	Drainage	Downstream renovations	Built	Rectangular + barrel vault

along undesirable routes, both of which were potential liabilities that could undermine the urban infrastructure (for other examples, see Hodge, 1992; Parise 2012; Parise et al., 2015).

Indeed, the studied systems suggest several utilitarian objectives (Table 1). A rock-hewn subhorizontal spring tunnel system was developed in order to maximize efficiency of water abstraction from a spring, such as Ras el 'Ein (Yechezkel & Frumkin, 2016). This is one of the most elaborate rock-hewn spring tunnel systems in the southern Levant. As in the case of a qanat, the spring tunnel system exploits groundwater, but its systematic features diverge from those of a qanat. A typical qanat is an unbuilt tunnel with shafts, collecting water along an unconsolidated aquifer and reaching the surface along a shallow gradient (along the traversed semiarid area) prior to reaching the valley area. A spring tunnel, such as Ras el 'Ein, is commonly hewn into bedrock at a mountain spring, in order to increase its discharge. In general, the earliest chronologic origin of such subhorizontal tunnel water abstraction systems can be traced to the late Iron Age (Yechezkel & Frumkin, 2016). The hewn tunnel of 'Ein Qaryun is considerably shorter than that of Ras el 'Ein, possibly indicating that the enhanced flow of 'Ein Qaryun was sufficient without a long hewn tunnel. Since the spring at Ras el 'Ein was outside the city, its waters could be consolidated for irrigation and powering mills (Fig. 4b). In this case, then, greater quantities of water were required.

The discharge patterns at the springs of 'Ein Qaryun and Ras el 'Ein fluctuated considerably between wet to dry seasons and between dry and wet years (Fig. 3). In addition, the demands for urban usage of water were larger during the day than for the night. Large capacity, centrally controlled reservoirs could store excess water for periods of shortage. Indeed, a system of masonry-built tunnels conveyed the water of all the studied springs to such reservoirs. The elaborate system of built tunnels leading northward from 'Ein Qaryun may underscore the distribution networks of water between users, and/or the changing modifications made in the system over ca. 2000 years of probable and variable usage. At Ras el 'Ein, a single built tunnel leading from the entrance structure to the reservoir is observed today, but additional transport systems may have existed. As the reservoirs are currently in use, they could not be checked during the present study. At 'Ein Dafna built tunnels conveyed the water to both sides of the water divide: eastward and westward. The western tunnel is the longest, conveying the water roughly in line with the main axis of the city. The topography and oral description (A. Naji, personal communication, 1977) indicate that the main tunnel continued to the WNW end of the city.

These observations raise the question as to whether or not the only purpose of this "main tunnel" was the transport of 'Ein Dafna's water. In Jerusalem, a Roman period subterranean tunnel was excavated along the Tyropoeon Valley, for draining runoff water (Reich & Shukron, 2007). Drainage was even more important in Ma'abarta—Neapolis, as the surplus spring water had to be diverted year-round, in addition to the need to regulate runoff during winter rainfall events. Thus it can be assumed that 'Ein Qaryun and Ras el 'Ein could have had some kind of overflow spillway trench or tunnel, connecting such flow routes to the main tunnel. However, such connection between the systems has not been identified during the present study or in other works (Sabri et al., 2015). It is probable that the main tunnel served to drain excess water from 'Ein Dafna, from the streets during torrential rainfall events, and possibly from influents from other springs. The shafts connecting the tunnel to the surface could be used for drawing water out of the tunnel, or alternatively for draining street runoff into the tunnel. Unlike a qanat the main tunnel conveys spring water rather than mobilizing groundwater. In terms of architecture, the main tunnel is ashlar built, unlike a qanat which is not. A qanat collects water along an unconsolidated aquifer, ultimately reaching the surface by a small gradient tunnel in a semiarid area, prior to arrival in a valley. The main tunnel of Neapolis does not share these features.

The great depth (14 m) of the main tunnel below the Roman *Decumanus* is puzzling, considering the investment in labor for building and covering a tunnel of such magnitude. By comparison the Jerusalem drainage tunnel is considerably shallower, attaining a depth of only a few meters (personal observation; Reich & Shukron, 2007). Why would the builders of Neapolis dig so deep and extensively for this water tunnel when a more northern and shallower route could have been more efficiently and simply excavated?

An indirect clue can be found in the writings of the famous historian Josephus Flavius. He reports that in 31 B.C.E.: "there was an earthquake in Judea such a one as had not happened at any other time and which earthquake brought a great destruction upon the cattle in that country. About ten thousand men also perished by the fall of houses…" (Antiquities 15,5,2). A similar report is found in another book of Flavius. (Wars 1,19,3) but the number of casualties mentioned there is 30,000. Based on these reports and archaeological evidence, it is agreed upon by most researchers that a strong earthquake of magnitude M_L ranging from 6 to 8 impacted the Holy Land in 31 B.C.E. (e.g., Amiran, Arieh, & Turcotte, 1994; Ben-Menahem, 1991; Karcz, 2004; Ken-Tor et al., 2001; Migowski, Agnon, Bookman, Negendank, & Stein, 2004). In addition, Neapolis-Nablus had suffered severe destruction and hundreds of casualties from many later earthquakes (and aftershocks), as it is erected on soft natural and anthropogenic sediments at the foot of a steep slope (e.g., Amiran et al., 1994). The 200 m lower slope of Mt. Gerizim attains its maximal steepness, 36°, above the excavated

Decumanus tunnel entrance (Fig. 4b). This is above the repose angle of most unconsolidated granular sediments (Lemaitre, 2002), suggesting instability of colluvial loose sediments.

In light of the above considerations, it may be tentatively suggested that the major earthquake of 31 B.C.E. triggered debris flows and structure collapse in Ma'abarta that had been built at the foot of Mt. Gerizim. The tunnel would thus have been covered by a thick deposit of debris. The *Decumanus* was subsequently constructed on top of this deposit, and a 14 m deep staircase would have had to be constructed through it, in order to connect this main road with the tunnel.

Additional lines of evidence may support the suggestion that the water system originated during the Hellenistic period. The names 'Ein Qaryun and 'Ein Dafna are themselves of probable Hellenistic origin (Magen, 2009). As the built area of Ma'abarta has not yet been documented archaeologically, probing through the tunnel systems may be the best way to penetrate the Hellenistic city to gain access for follow up field study.

Tunneling techniques for waterway networks were well-established in the ancient world during the Hellenistic period (e.g., Angelakis & Spyridakis, 2010; De Feo et al., 2013; Frumkin & Shimron, 2006). In the land of Israel, the construction of long water tunnels had already been initiated by around 700 B.C.E. and perhaps earlier (e.g., Frumkin, Shimron, & Rosenbaum, 2003; Shiloh, 1992). Those networks were commonly utilized during the Hellenistic period (e.g., Amit & Gibson, 2014; Frankel, 2002; Frumkin, 2015).

Barrel-shaped vaults of well-cut ashlars are common in the roofs of most studied water systems in Ma'abarta—Neapolis, including 'Ein Qaryun, Ras el 'Ein, and the main tunnel. The barrel-vaulted tunnels are generally nested deep below the present surface, and also well below the surface of Roman Neapolis, up to 14 m in the main tunnel (see above).

The construction of barrel vaults became popular in Israel since the Hellenistic period (Netzer, 1992), and is particularly common in Hellenistic underground systems, such as the aqueduct of Akko-Ptolemais (Frankel, 2002), The Biyar and Solomon Pools springs leading to the low-level aqueduct to Jerusalem (Amit & Gibson, 2014; Mazar, 2002) and at the underground systems of Maresha (e.g., Kloner, 1993). During Hellenistic times these vaults apparently became the construction style rather than a constructional necessity, because some vaulted tunnels are narrow and close to the surface, where they could be safely covered with slabs of stone, without inducing tensile stresses in the stone slabs. On the other hand, roofing by horizontal stone slabs was practiced during other Classical periods in Israel, as evidenced by the renovations in parts of the main tunnel of Neapolis.

The above observations coupled with the deep level of the Qaryun and the main tunnel vaults below the remains of Roman Neapolis converge around a Hellenistic age of origin for many of the water tunnels discussed here. If so, these collective findings can represent remnants of the enigmatic Hellenistic town Ma'abarta which had existed at this location for over 180 years since the 3rd century B.C.E. (Magen, 2009, p. 355). Further additions, modifications and maintenance of the systems took place during the last two millennia, and reflected a variety of architectural styles.

The entire water system provided appropriate solutions for several utilitarian needs: enhancing spring discharge, conveying the water to reservoirs, and draining excess water of springs and rainfall. However, some architectural features may signify more abstract purposes, such as pagan water ritual.

The apsidal semidome structure of 'Ein Qaryun is similar to that occupying the ancient entrance chamber of the 'Ein Harun spring tunnel at Naqura, 7 km NW of 'Ein Qaryun. Braslavski (1924–1925) suggested that pagan ritual was practiced at 'Ein Harun spring. Like 'Ein Harun, the finely built entrance structures of 'Ein Qaryun and Ras el 'Ein are too elaborate for utilitarian access for water quality control. With caveats, one can raise the possibility that some form of (regional) water-linked ritual may have been practiced at major springs during the pagan period of city occupation. Ritual pagan usage of springs associated with underground cavities can be compared to those postulated for other southern Levantine sites, including Caesarea Philippi—Banias (Berlin, 1999), Te'omim Cave (Zissu et al., 2011), and Afqa (Garreau, 2011).

A historic source seems to support a long history of ritual use in a spring cave at Mt. Gerizim, most probably Ras el 'Ein. The medieval geographer Yaqut al-Hamawi wrote around 1225 C.E.: "The Mountain (Gerizim) is mentioned in the Pentateuch. The Samaritans pray towards it. There is here a spring in a cave which they venerate and pay visitation unto" (quoted in Le-Strange, 1965, p. 513). Preserving ancient pagan rituals was attributed to the Samaritans by several historic sources since biblical times (e.g., Kings 2,17, pp. 24–34). A Samaritan cemetery situated around the Ras el 'Ein entrance structure supports the possible identity of Ras el 'Ein as the spring cave of Mt. Gerizim that was venerated by the Samaritans, per the account of Yakut.

5 | CONCLUSION

The underground water systems within Ma'abarta—Neapolis seem to be more elaborate than those characteristic of most other southern Levantine cities. These subterranean hydrographic systems were used for water mobilization and conveyance. Their widespread and complex utility was a function of the abundance of large springs inside and close to the city. Spring resources here were unequalled in other southern Levantine cities. The unique networks also explain the rarity of an urban rainfall harvesting system. They stood in contrast with those of Hellenistic-Roman Jerusalem where the only spring is located at the lower end of the city, and was too limited to provide water for increased urban populations and needs. For the same reason, Ma'abarta—Neapolis did not need any aqueducts to import water from a distance, unlike such nearby southern Levantine cites as Sebaste, Jerusalem, Caesarea, Akko—Ptolemais, and Dor.

Three types of tunnels were observed in Ma'abarta—Neapolis: (1) subhorizontal rock-hewn tunnels for abstracting groundwater; (2) masonry-built tunnels conveying water from the source toward the users/reservoirs; (3) masonry-built main drainage tunnel.

The main tunnel ran along the city of Neapolis, from 'Ein Dafna toward the WNW end of the city, along Nahal Shechem. Along its course, it was possibly joined by ancillary tunnels accommodating intermittent or seasonal overflow of major springs, Ras el 'Ein and 'Ein Qaryun, whose upstream tunnel systems are reported herein. The present data do not support water abstraction along the main tunnel. Most likely, that structure was used to convey surplus water from 'Ein Dafna and possibly other springs. The findings of this study corroborate the report of Ahmad Al-Ya'qubi, that "Under the town is an underground city hollowed out in the rocks."

The 14 m elevation difference between the *Decumanus* and the underlying main tunnel, suggests that this tunnel had already been built during the Hellenistic occupation of Ma'abarta. This deduction is supported by the dated barrel-vaulted water tunnels diagnostic of some other regional Hellenistic drainage systems. It follows that Ras el 'Ein, as well as part of 'Ein Qaryun system may also date to the Hellenistic period. The 31 B.C.E. earthquake could be responsible for the thick debris that accumulated above the tunnels, as the city was highly vulnerable to earthquakes.

The elaborate architecture of spring-based entrance structures may indicate that the main springs in and around Neapolis may have been used as sites for pagan worship. That association may relate to a later manifestation, a Samaritan holy site within a spring cave at Mt. Gerizim. These chronological linkages require additional validation such as documentary and archaeological evidence.

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