ARTICLE

# A Spatial Network Analysis of Water Distribution from Public Fountains in Pompeii

MATTHEW NOTARIAN

*Supplementary Online Figures and Appendix*

The transport of water from street fountains into living spaces was tedious but essential labor that impacted the health and social integration of subelite populations, yet it remains understudied in work on Pompeii's public water system. This article uses spatial network analysis to demographically model public fountain use at a unit-level scale. Dynamic neighborhoods are identified using least-cost routes between every external door and fountain in the city. Maximum and minimum ranges of labor and water accessibility are quantified by total daily time and energy fetching water per household, aggregate pedestrian traffic to fountains, and fountain crowding or underuse. Data are contextualized within disruptions to the water system from seismic events in the city's final decades, the contributions of cistern and private water lines to daily needs, and comparative and primary textual evidence for the socioeconomic status and well-being of water fetchers. The results expose disproportionate inequality at the system's peripheries, although most residents enjoyed good water access. Moreover, they reconstruct the scale of labor of marginalized sectors of Roman society that is underrepresented in textual and artistic sources, offering quantifiable comparanda for further studies on water accessibility in antiquity.[1]

## INTRODUCTION

Public water sources were critical pieces of infrastructure in the premodern city. Wells, fountains, cisterns, and springs were central to the maintenance of public health and well-being. Great care and expense were invested in their construction, distribution, and upkeep. In many respects, publicly accessible water features also shaped the spaces and cadence of daily life, channeling movement through streets and cultivating social interactions. Given the difficulty of hauling water long distances, and barring complicating factors such as uneven quality, inadequate supply, or overuse and crowding, city dwellers frequented the closest sources, creating de facto urban districts or neighborhoods.[2] Spatial distribution of water sources also strongly impacted

[1] I am indebted to numerous people who kindly offered advice, data, resources, and other feedback throughout my work on this project. In particular, I wish to thank Christopher Higgins, Taylor Lauritsen, Grant McCall, Maria Monteleone, Jenny Muslin, Seth Pevnick, Eric Poehler, Dylan Rogers, Eppu Viitanen, and Rhodora Vennarucci. I also greatly appreciate the assistance of *AJA* Editors-in-Chief Emma Blake and Robert Schon, and the anonymous reviewers, for their thoughtful and helpful comments. Figures are my own except as noted. Supplementary figures and appendix are available online at https://doi.org/10.1086/722233. More detailed quantitative data can be accessed via an interactive map at https://mnotarian.github.io/Pompeii_Fountain_Map/. Abbreviation MP = Márquez-Pérez et al. 2017; MT = a modified version of Tobler's Hiking Function, Tobler 1993.

[2] Laurence 2007, 38–44.

*American Journal of Archaeology*
Volume 127, Number 1
January 2023
Pages 85–118
DOI: 10.1086/722233

www.ajaonline.org

water accessibility across urban landscapes, constructing a hierarchy of privilege with respect to this vital public resource. In short, water sources demarcated the boundaries and patterns of an important, but by no means sole, social geography of the city, with significant ramifications for everyday lived experiences. The labor of water carriage, however, was distributed unevenly across space and social class. Its weight fell heaviest at the margins of Roman society, on those who relied on or were tasked with manual daily transport of water from public sources into homes and businesses. Recovering and reconstructing the network's structure sheds light on the lives and labor of the classes most underrepresented in the material and textual record.

The excellent preservation of Pompeii's road network, housing core, and hydraulic infrastructure presents a rare opportunity to heuristically model water fetching in street-by-street, unit-level detail. In recent decades, innovative analyses have pushed the boundaries of Pompeian studies into stimulating new territory. Movement and mobility, the circulation of wheeled and pedestrian traffic, and the social context of Pompeii's streets have been investigated from a variety of perspectives, ranging from space syntax analysis to holistic reconstructions of its experiential and sensory dimensions.[3] Concurrently, deep readings of both material and textual sources, especially graffiti, focused on elucidating the lives of the most marginalized and invisible communities, such as the enslaved and prostitutes, have challenged us to reexamine familiar evidence with an eye toward uncovering these hidden agents.[4]

This article seeks to situate Pompeii's public fountain network within this context. Foundational studies by Eschebach and Laurence on its infrastructure, spatial distribution, and social function are now joined by a flourishing interest in Roman water studies that place Pompeii in a much broader framework.[5] Others explored the fountains' economic impact and interruption of private and public spaces.[6] Yet Laurence's hypothesis that fountains delineated the confines of identifiable neighborhoods remains an intriguing, if not fully explored, thesis. New methodologies born out of the spatial turn in Roman studies and the growth of GIS and network analysis in archaeology afford new prospects to revisit and refine interpretations of fountain activity and its varied effects. Least-cost analysis is commonly used to model movement and identify routes across archaeological landscapes, yet it has only rarely been applied at the scale of urban street networks.[7] Nonetheless, groundbreaking *spatial* network analyses—those that embed topology in physical space—have demonstrated that computational network methodologies hold great potential to quantitatively analyze intrasettlement movement. Yet by focusing solely on global (the so-called "from everywhere to everywhere" approach) or single-destination analyses, they understate these applications' capacity to clarify concurrent travel between multiple dispersed locations and to therefore model historically identifiable spatial activity.

Daily water collection from public fountains in Pompeii is evident from use-wear on extant basins, written sources, and the network's careful distribution. Unlike earlier studies that approached the activity through abstractions such as 50 m radius circles or Thiessen polygons, this analysis calculates fountain usage within a network of doors and fountains linked by streets—the very routes traversed by water fetchers in antiquity.[8] This method not only calculates more accurate distances from buildings to fountains than straight-line measurements, it quantifies movement in units of time and energy, which are arguably closer to how an ancient inhabitant perceived and chose intraurban routes. Significantly, this model demonstrates that earlier visions of self-contained neighborhoods centered on a single fountain were too simplistic. Rather, communities of fountain users resided in more nuanced and dynamic overlapping districts determined by individual agents' choices. Furthermore, at its household-level scale, these neighborhoods are here quantified by unit count, size, function, time, energy, and minimum and maximum population estimates. Street activity is

[3] Laurence 2007; Kaiser 2011; Laurence and Newsome 2011; van Nes 2014; Hartnett 2017; Poehler 2017b.

[4] Joshel and Petersen 2015; Benefiel 2016; Keegan 2016; Levin-Richardson 2019; Ancient Graffiti Project (http://ancientgraffiti.org).

[5] Eschebach 1979; 1982; Eschebach and Schäfer 1983; Laurence 2007, 38–44. For water studies, see Rogers 2018. See also infra n. 9.

[6] Ling 2005; Poehler 2017b, 174–79.

[7] Wernke 2012; Poehler 2017a; Wernke et al. 2017. On least-cost analysis in archaeology, see Siefried and Gardner 2019; Herzog 2020.

[8] Eschebach 1979, fig. 11; Laurence 2007, map 3.4.

similarly measured through aggregate pedestrian traffic along routes. Overall, the results reconstruct the scale of labor of marginalized sectors of Roman society and offer quantifiable points of comparison to contemporary worldwide water provision.

## THE PUBLIC WATER SYSTEM AT POMPEII: CONTEXT AND COMPLICATIONS

Thanks to the unique scope of its preservation, Pompeii's public water infrastructure has been studied intensively, particularly in the last couple of decades.[9] The situation is far from ideal, however, and is complicated by several factors, including service disruptions in the city's final decades stemming from one or more earthquakes, bradyseism, possible pipe salvaging after the Vesuvian eruption, and a long excavation history often lacking adequate record keeping, systematic methodologies, or well-documented conservation.[10] As a result, several key facts remain unresolved, such as the source and route of the aqueduct supplying the city, the date of its first introduction, the main pipe network's urban path, the volume of water delivered, and the exact numbers of private houses and commercial properties with connections to the piped network, especially in Pompeii's final years. The aqueduct's use must also be analyzed in the context of an earlier system of public and private wells and cisterns that was certainly transformed by its introduction but by no means completely abandoned.[11] While several public and private wells were filled after the Augustan period, others were covered and preserved for potential future use, and formerly public ones were privatized.[12] Most private cisterns continued to collect rainwater, and many also captured runoff from private piped connections.[13]

Pompeii was provided with piped water from the Augustan period, at the latest, most likely via the Aqua Augusta (Serino) aqueduct, entering from the *castellum aquae* near Porta del Vesuvio and distributed to a network of public fountains, baths, private homes, and businesses (the last two collectively referred to here as units), through a series of strategically located water towers. Recent studies identified up to 113 units that had, at one point in time, a private water connection to the aqueduct system.[14] This number was probably higher, though, as suggested by the number of pipe impressions in calcium carbonate (sinter) on water towers and additional homes with fountains but no extant evidence of external pipes.[15] It is also certain an undefined number of houses were no longer connected to the piped-water network at the time of the eruption, most likely due to seismic events, either the earthquake testified by literary evidence in 62/63 CE or an undocumented more recent event prior to 79 CE.[16] The disruption's extent and status have also been an ongoing source of scholarly contention.[17] Recent syntheses suggest a temporary pipe network had been installed immediately before the 79 CE eruption that prioritized supply to public fountains, but an undetermined number of homes maintained private waterlines, possibly due to fortuitous location in the larger water system.[18]

## THE PUBLIC FOUNTAIN NETWORK AT POMPEII

The public fountain system at Pompeii was extensive, but uniform neither in type nor distribution, despite this characterization (fig. 1).[19] Up to 46 public fountains are identified in the city's excavated regions,

[9] E.g., Eschebach 1979; Ohlig 2001; Jansen 2002; Schmölder-Veit 2009; de Haan 2010; Dessales 2013; Olsson 2015.

[10] Nappo 2002; Bruun 2012, 146–47; Dessales 2013, 250–74; Keenan-Jones 2015.

[11] E.g., the forum cistern was converted to a sewer in the Early Imperial period; Schmölder-Veit 2009, 119.

[12] Maiuri 1931; Richardson 1988, 51–53; Schmölder-Veit 2009, 132; Ellis et al. 2011, 5–6; Keenan-Jones 2015, 196. One was reused as a cistern in 79 CE; see Descoeudres and Sear 1987, 28.

[13] Dessales 2013, 219–21, 291–316. Some were filled concurrently with the aqueduct (e.g., Ellis and Devore 2010, 7–8).

[14] Jansen (2002, 48) identified 90 intramural units with definite connections to the public water system. Dessales (2013, 397–494) catalogued 92 units, many of which were inferred but not confirmed. Since Dessales did not consult Jansen 2002, only 69 units were common to both, a total of 113.

[15] Jansen (2002, 48) counted 107 pipe impressions, but three towers (nos. 10, 12, 13) had no extant sinter buildup. Andersson (1994) counted 160 units with fountains, but this is certainly too many as it double counts some houses with multiple fountain groups and probably includes fountains fed by raised rainwater tanks (see Jansen 2002, 48 n. 204). Dessales (2013, 397–494) catalogued 117 houses with fountains, 92 of which connected to the aqueduct.

[16] E.g., House of the Vestals (VI.1.7). See Jones and Robinson 2005.

[17] Dessales 2013, 250–51; Keenan-Jones 2015, 191–200.

[18] Leander Touati 2010, 120–26; Keenan-Jones 2015, 199.

[19] Eschebach 1979, 11: "fast regelmäßigen Abständen über das gesamte Stadtgebiet verteilt" (with 50 m catchment areas); Hodge 2002, 305: "fairly evenly spaced intervals of about 100 m."

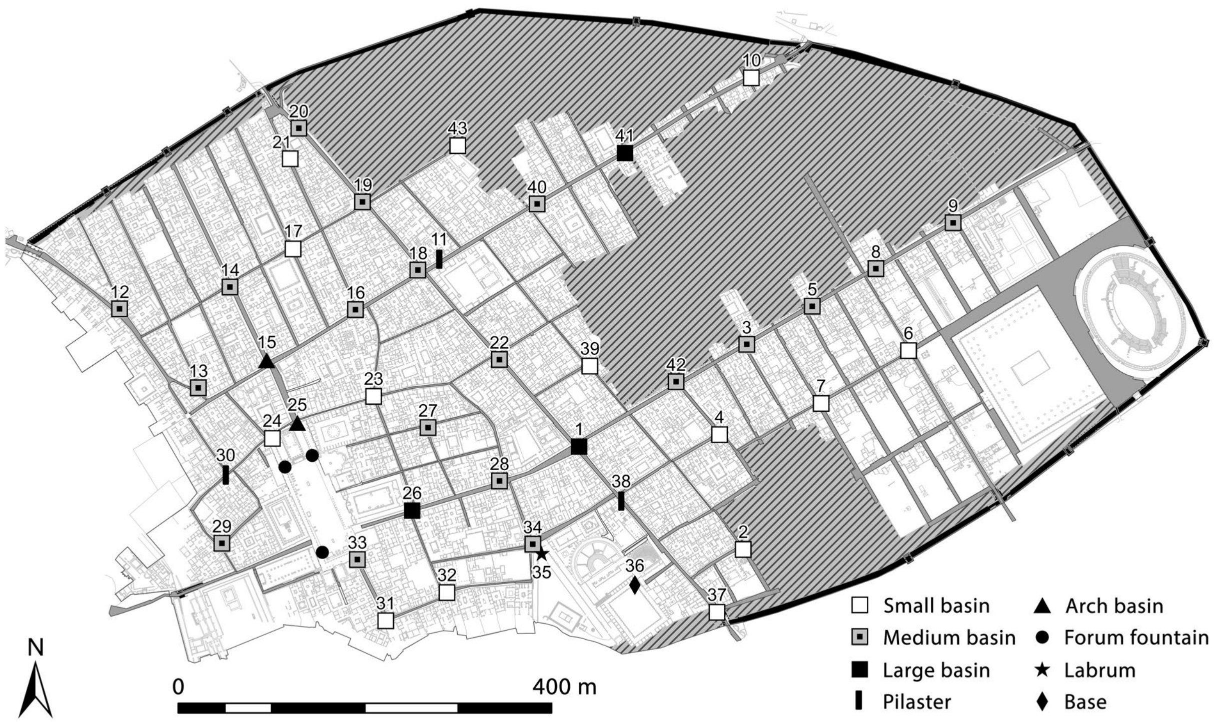


FIG. 1. Public fountain network in Pompeii by type and size; small basin = 300–700 liters, medium basin = 701–1000 liters, large basin = 1001–1400 liters (numbering follows Eschebach and Schäfer 1983 except for no. 43).

consisting of varied types, materials, and, likely, function and chronology.[20] The most common and iconic variety are the 36 fountains with basins composed of large rectangular stone blocks joined with bronze or iron clamps and paved with *opus signinum* or mortared tiles (fig. 2).[21] Water flowed from a spout, often decorated with a variety of reliefs, including heads of deities and animals, or objects, mounted on an adjoining taller stone column that also supported lead pipes. Their iconography typically refers to water or religion and does not seem to correspond with civic or neighborhood identities, despite attempts to link them.[22] An overflow channel carved into the basin indicates water sometimes flowed into the streets, while a separate hole on the bottom, usually plugged, was reserved for cleaning and maintenance.[23] It is probable these types are those referred to as *lacus* in literary and epigraphic texts.[24] Similar public fountains are known at other Roman cities in Italy and the western provinces, but the series from Pompeii are the most complete and well-preserved.[25] Nonetheless, the Pompeian basins do not form a homogeneous group

[20] Eschebach 1979, 11–13; 1982; Eschebach and Schäfer 1983; Richardson 1988, 57–60; Nappo 2002, 92–97. The Grande Progetto Pompei uncovered the latest in 2018. A possible 47th example outside Porta Ercolano on the north side of Via dei Sepolcri at 20A, between tabernae 20 and 21, consists of only a basin in *opus incertum*, lacking the usual associated pilaster and spout; Emmerson 2020, 140; Zanella 2021. Eschebach 1982, 21–22, fig. 6; Eschebach and Schäfer 1983 (cat. no. 43) catalogued another based on a now lost tuff fountainhead with a male deity in relief discovered in 1757 (Fiorelli 1860–64, 1:51) near Via dei Sepolcri. This study only considers intramural fountains.

[21] Eschebach and Schäfer (1983) recorded 35. Their numbering is used here. However, the newest fountain in Regio V (intersection of Vicolo delle Nozze d'Argento and Vicolo dei Balconi) is numbered 43 in place of the previously catalogued lost fountain (see supra n. 20).

[22] Eschebach and Schäfer 1983; Schmölder-Veit 2009, 130–31.

[23] According to Frontinus (*Aq.* 2.103–4), public fountains in Rome were required by law to flow continuously day and night. There is no evidence Pompeian public fountains could be turned off; Monteleone et al. 2021.

[24] E.g., an inscribed monolithic fountain basin from Trebula Balliensis (Campania; *CIL* 10 4561) commemorates the town's aqueduct and fountains (*lacus*) by *quattuorviri quinquennales*. *Lacus* predominantly refers to public water basins rather than private; see Dessales 2013, 54–55.

[25] Agusta-Boularot 2008.

FIG. 2. Basin fountain no. 28 in Pompeii (R. Vennarucci; by permission of the Ministry of Culture – Archaeological Park of Pompeii).

despite their similarity. The majority are built in lava stone, but three are travertine, two in tuff, and two isolated examples are marble and concrete, respectively. The size, shape, and arrangement of the rectangular blocks also vary. Importantly, the basins differ in both area and volume but seem to cluster around three or four sizes (online appx. table 1).[26] This variation signals they were not designed for an even distribution of water; rather, differential consumption was expected. Moreover, the volume of three basins (nos. 6, 24, 37) was later reduced by raising their bases, possibly in reaction to reduced flow.[27] Functionally, the basins were intended for more efficient water distribution. Rather than filling vessels one at a time from the spigot, several users could be accommodated at once by dipping their containers into the pools, provided enough surplus had collected.[28]

These fountains were supplemented by a variety of other similarly public facilities. Three fountains consisted of only a stone pilaster and spout, lacking a basin (fig. 3). Their function has been questioned, since two of the three examples have large curbstones at their

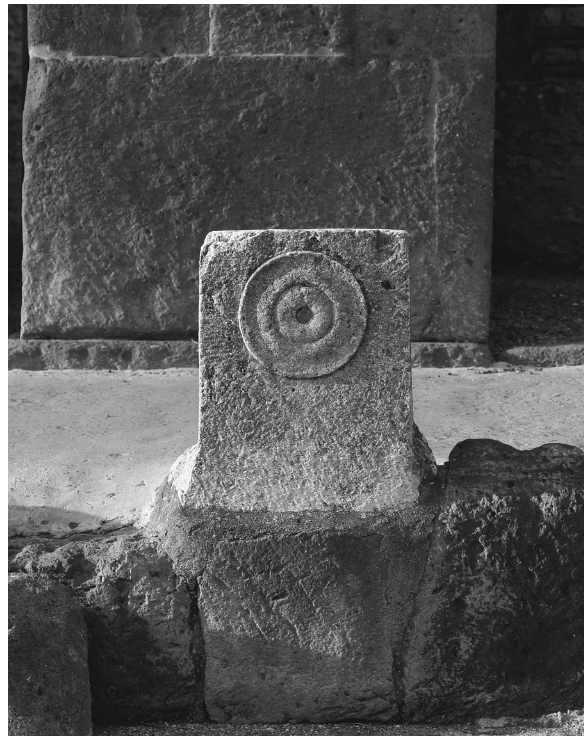

FIG. 3. Pilaster fountain no. 11 in Pompeii, with unobstructed access (R. Vennarucci; by permission of the Ministry of Culture – Archaeological Park of Pompeii).

bases to protect them from carts.[29] These stones would have limited the size of any vessel placed underneath to collect water or render it inconvenient, at least. As a result, many believe they were intended for drinking only.[30] Others have interpreted their function in relation to nearby cult or industrial facilities and see them possibly installed through private benefaction or other legal means for using unused overflows (*aqua caduca*) that were reserved for baths and fullers.[31] Additional fountain basins were incorporated into the so-called Arch of Caligula's southern piers on the Via di Mercurio and the so-called Arch of Nero's northern piers at the forum's northeastern corner. The former were

[26] Nappo (2002, 93–94) recognized five types based on slab arrangements. Nishida (1991, 91–96) described eight construction types and three size categories. Schmölder-Veit (2009, 128 n. 149) classified three types by volume, while Olsson (2015, 50, 102–3) defined four. The appendix is available online at https://doi.org/10.1086/722233.

[27] Monteleone et al. 2021.

[28] Jansen (2002, 45–46) estimated six to eight people could fit around the larger basins at once, although street traffic or the lower street level might have restricted access to sidewalk sides (hence only one or two people at a time). Wear is often clustered on these sides; Monteleone et al. 2021, n. 7.

[29] Fountains nos. 30 and 38; no. 11 is unobstructed.

[30] Eschebach and Schäfer 1983, 31; Jansen 2002, 47; Staub 2013, 23. Contra: Schmölder-Veit (2009, 129 n. 164), who contends containers could be placed underneath.

[31] Dessales 2011, 139–42; Staub 2013, 23. On *aqua caduca*, see Frontin., *Aq.* 2.94, 110–11; *CIL* 2 5439 = *ILS* 6087 (*lex Ursonensis*: 100); de Kleijn 2001, 93–98. No. 11 was possibly provided for industrial use in a nearby dyer's shop (*officina infectoria*) that lacked piped water. No. 38, located in front of the so-called Temple of Jupiter Meilichios/Aesculapius, might have been provided for religious rites. See also infra n. 42.

removed in antiquity, however, probably after the earthquake(s) of 62/63 CE.[32] The latter retain some marble revetment and fluted column bases (in the eastern basin) that once adorned them, but they may never have been employed prior to the city's destruction.[33] Although marble would have presented a monumentalized appearance befitting the public nature of this space, their orientation away from the forum toward the Via degli Augustali to the north suggests a utilitarian function much like the *lacus* fountains. Three large basin fountains were also installed on the forum colonnade's broad exterior step, perhaps in the Early Imperial period. Like the fountains on the Arch of Caligula, however, these were also later systematically removed, perhaps after damage from the earthquake(s) of 62/63 CE.[34] Although it is difficult to draw conclusions from the limited remaining evidence, these fountains were nearly twice as big as even the largest street fountains, likely reflecting a similar dual functionality: luxurious showpieces for the city's hydraulic system and practical clean water sources for its residents.[35]

Finally, two more fountains were in the Triangular Forum and the quadriporticus behind the large theater. The first took the form of a marble labrum that received water from a spout mounted on an adjacent fluted Doric column. The latter, in the northeast porticus corner, consisted of a rectangular marble base with four lion spouts. In a watercolor by W.J. Hüber dating to ca. 1818–19, it appears to have an associated basin as well.[36] It was removed in the early 19th century and subsequently lost.[37] While both were in spaces with a certain public character, they were peripheral, with possible limited access. This probably meant they were not intended for everyday household water collection. Nearby units had more accessible options.[38]

The fountain system was presumably installed contemporaneously with the introduction of aqueduct water to the city, most likely in the Augustan era, however, there is perhaps evidence for an earlier external water system.[39] The *lacus* type is already attested by the mid first century BCE in Italy but spread in popularity during the reign of Augustus.[40] Logically, the basin fountain series at Pompeii would seem to have been constructed as part of a unified project related to the new public system.[41] Yet the varied forms, materials, relief quality, and sizes of the public fountains across the city hint at a system that may have been built in stages, or repaired or added to over time by municipal authorities or private benefaction.[42]

[32] Sinter in masonry pipe recesses of the Arch of Caligula (Larsen 1982, 59; Keenan-Jones et al. 2011) indicates fountains were installed at the base of the piers on its south face. They were removed after the earthquake(s) of 62/63 CE, when the street was repaved, perhaps in coordination with installation of new fountains in the Arch of Nero to the south (Poehler 2011, 151; Poehler and Crowther 2018, 596, fig. 14).

[33] Maiuri (1973, 123) found two pipes under the west side of the western pier of the Arch of Nero that were cut and closed off, possibly awaiting installation of a new water system before the eruption. Portions of lead piping were still in place within one or both basins in the 19th century (see, e.g., Rolf 1884, 14).

[34] Only traces of waterproofing, drains, and channels survive. Two were located east and west of the Capitolium facade. The third, outside the basilica, was rectangular with two frontal apsidal niches. These were not documented by Eschebach and Schäfer (1983). See Richardson 1988, 264; Kockel 2005, 64; Schmölder-Veit 2009, 131–32.

[35] Ca. 2.5 m long and between 1.2 and 1.4 m wide. The largest street fountain (no. 26) was about 1.5 m long by 1.0 m wide.

[36] Reproduced in Poehler and Ellis 2014, fig. 6.

[37] Eschebach (1982, 22; Eschebach and Schäfer 1983, 28–30) dates its disappearance to 1810, while Poehler and Ellis (2014, 4) note its appearance in plans and paintings until ca. 1837.

[38] E.g., fountain 34 is directly outside the Triangular Forum's entrance.

[39] The predominant theory holds that Pompeii was connected to the Serino aqueduct in the Augustan period. Ohlig (2001) proposed an earlier, possibly Sullan, aqueduct sourced above Avella, which continues to be debated; e.g., pro: Wilson 2006; Bruun 2012; Dessales 2013, 217–18; contra: Schmölder-Veit 2009, 119–21; Keenan-Jones 2015, 194–95; 2016, 783. Summarized by Keenan-Jones (2015, 200–2).

[40] Agrippa installed hundreds in Rome (Plin., *HN* 36.121). Contemporaneously, the form appears archaeologically in the Gallic provinces and the term *lacus* became definitively associated with public fountains; see Del Chicca 1997, 231–37; Agusta-Boularot 2008.

[41] On fountain and tower placement in relation to existing street frontages, see Ling 2005. On their effects on traffic systems, see Poehler 2017b, 174–79. A unified public construction scheme is attested at Paestum by a series of 14 limestone blocks with holes and traces of lead piping, similar to the Pompeian fountain columns, inscribed by the *duoviri* by decree of the local senate (e.g., *CIL* 1 3157a). Their connection to a new aqueduct is testified by *AÉpigr* 1995, 387 (see Mello 1995, 110–11).

[42] Eschebach and Schäfer (1983, 31) and Richardson (1988, 58) hypothesized that marble and travertine basins were later private additions. Staub (2013, 23, 94) suggested the pillar fountain (no. 11) outside the Casa del Torello di Bronzo (V.1.7) might have been supplied by the house owner, as evidenced by a connection diverting from an interior distribution box rather than directly from a water tower. Dessales (2011, 142) observed that both this fountain and nearby basin fountain no. 18 are travertine, suggesting a common installation. Mau (1895,

This remains difficult to prove, however, given the uncertainties surrounding the aqueduct's date and the absence of epigraphic or stratigraphic data for the fountains themselves.

## PRIVATE CISTERNS, PIPED CONNECTIONS, AND THE POSTAQUEDUCT WATER SYSTEM

The coexistence of multiple water sources in Pompeii, as in many ancient cities, has led to varying emphasis on their relative importance and use. Before the aqueduct, water was collected from wells and cisterns exclusively, which must have been used for all needs: drinking and cooking, personal hygiene, household cleaning, irrigation, and industry.[43] Once piped water was available, this additional supply ought to have supplemented or substituted for some demands. Well water seems to have been largely abandoned at Pompeii after the Augustan period, as were some public cisterns, but private cisterns remained widely maintained. Certainly, aqueduct water was essential when it came to supplying both public and private baths, as well as fountain displays in private homes, but many studies downplay or deny its use for cooking and drinking. This seems counterintuitive, as the constantly flowing system would have rendered it the cleanest available water.[44] Moreover, some have interpreted Vitruvius' description of a tripartite *castellum aquae* as reflecting the priority of public fountains in urban piped water distribution.[45] Not all studies, however, have recognized an integral role for public fountains in fulfilling the daily needs of Pompeii's inhabitants.

Dessales, for example, has demonstrated that cisterns in various townhouses and shops could have supported reasonable population estimates using only rainwater reserves.[46] This is not surprising, since Pompeii existed for centuries without an aqueduct. Yet Dessales almost entirely omitted the contributions of public fountains toward supplying the needs of the city's residents, except in the case of upper-floor apartments with external stairs, or specific structures where cistern capacities seem to have been too limited to meet essential needs.[47] The construction of a widely distributed public fountain system across the city, however, certainly demonstrates a perceived public demand or need for such a supply.[48] This is underlined by evidence that they were prioritized in the decades after the 62/63 CE earthquake(s) by temporary pipes laid along the sidewalk surface, while many private homes that were previously supplied with tap water were disconnected.[49] Without doubt, collecting water from public fountains would have been less convenient and more labor intensive than drawing from cistern wellheads inside a home or shop, yet use-wear on the stones of most public basins in the city indicates many residents did just this (fig. 4). This extra labor would be justifiable if the city's inhabitants perceived differences in quality or use between cistern and piped water.[50]

---

49–50) observed some fountain bases (mainly private, except for one in the Triangular Forum) with Oscan mason's marks. Eschebach and Schäfer (1983, 30) and Nishida (1991, 93) speculated tuff fountains might be pre-Augustan, but Keenan-Jones (2015, 194–95) and Schmölder-Veit (2009, 125–27) are skeptical without any definitive evidence for piped water within the city before the Augustan era. On the relief decoration's varied quality: Schmölder-Veit 2009, 130–31.

[43] On wells in Pompeii: Jansen 2002, 20–22; Schmölder-Veit 2009, 116–19; on cisterns: Jansen 2002, 22–26; Schmölder-Veit 2009, 119–20, 132–34.

[44] Notwithstanding the presence of lead in piped water systems, and whether their dangers were understood (e.g., Vitr., *De arch.* 8.6.10); see Keenan-Jones et al. 2011.

[45] Vitr., *De arch.* 8.6.2; Dessales 2011, 138 n. 5. Cf. Hodge 2002, 280–82.

[46] Dessales 2013, 307–16. Largely estimated from roof catchment areas, since not many cisterns are fully excavated. The actual number and average capacity of cisterns across the city is unknown. Jansen (2002, 77 n. 88) collected capacities for eight cisterns.

[47] Dessales (2013, 310) calculated (roof catchment area) that a cistern in the House of the Prince of Naples (VI.15.8) would have provided only 10 liters per inhabitant per day, using Strocka's (1984, 50) upper household population estimate (20 people). A similar calculation (Dessales 2013, 312–13) using historical rainfall data and known cistern capacities in the Insula Arriana Polliana (VI.6) found a shared cistern beneath six shops (VI.6.2–4, 21–23) would have never filled more than two-thirds to capacity during winter, and would have been nearly empty by late summer, given a population of 30 people using 25 liters per day.

[48] Similarly, a series of public and private wells supplemented the pre-aqueduct system, further proof that cistern water alone was not sufficient with respect to either quantity or quality.

[49] Jones and Robinson (2005, 703) found a postearthquake pipeline that bypassed all adjoining houses in favor of supplying fountain 12 at the southern end of insula VI.1.

[50] According to the World Health Organization (2017, 94–96), rainwater catchment systems can provide safe, low risk drinking water, but only with careful planning and management. They are easily contaminated by environmental hazards (e.g., insects, feces, refuse, and dirt). For Pompeii, however, it is important to consider ancient theories of water safety and quality.

FIG. 4. Basin fountain no. 16 showing use-wear (arrow) beside the column (R. Vennarucci; by permission of the Ministry of Culture – Archaeological Park of Pompeii).

Ancient textual sources on water quality have been brought forth to argue in favor of one supply or another, but this evidence is contradictory and ambiguous at best.[51] On the whole, ancient writers viewed running water as preferable to still or stagnant in nearly all cases.[52] This would seem to accord with a general preference for aqueduct water wherever available, although, in Rome, specific lines were viewed as unsafe for human consumption.[53] Yet, at the same time, many writers also expressed a clear belief that rainwater was the healthiest due to its "lightness," which would seem to correspond with an inclination toward cistern water.[54] Nonetheless, cisterns seem to be denigrated by implication since stagnant water was held in disdain, including rainwater after it had settled.[55] This was often not expressly linked to cisterns, except for Pliny the Elder who condemned their cleanliness, describing them as often filled with slime and living creatures that cause intestinal illnesses.[56] In many instances, water drawn from cisterns was deemed a fallback in situations where no better (usually flowing) sources were available. Varro (*Rust.* 1.11.2) ranked cistern water third in order of preference after springs and streams. Columella (*Rust.* 1.5.1–4) also placed cistern water third in quality after springs and wells, with only swamps lower. Nevertheless, within this third category he praised cisterns filled with rainwater as the overall best for health, hence the paradox.[57] Roman law, however, specifically excluded cistern water in an interdict guaranteeing continued individual access to springs, lakes, or wells on public or private land because it was not perpetual and therefore not fresh.[58] Aristotle thought cistern water should only be used in emergencies, such as a siege, and urged that potable water (from springs) be stored separately from that reserved for other uses.[59] Similarly, according to Pausanias, some communities used rainwater only for

[51] Hellmann 1994; Richard 2012, 176–80; van Tillburg 2013; Klingborg and Finné 2018, 120. On qualities of water in Roman thought: Rogers 2018, 4–10.

[52] Concisely stated by Theophrastus (quoted in Athenaeus, *Deipnosophistae* II.42c): τὰ δ' ἐπίρρυτα καὶ ἐξ ὀχετοῦ ὡς ἐπίπαν βελτίω τῶν στασίμων (running waters, including those drawn from an aqueduct, are as a rule better than standing water); trans. Gulick 1927.

[53] E.g., according to Frontinus (*Aq.* 1.11, 2.91–92), the Alsietina and Anio Vetus were only suitable for irrigation, watering gardens, and "the more base needs of the city" (in ipsius urbis sordidiora . . . ministeria) due to poor quality.

[54] As concluded by Dessales (2013, 303–5). On a preference for rainwater: Celsus, *Med.* 2.18.12; Palladius, *Opus Agriculturae* 1.17.4; Vitr., *De arch.* 8.2.1.

[55] Theories that rainwater quickly lost health-giving qualities are found in the Hippocratic corpus (*Aer.* 8) and Pliny (*HN* 31.32–34). The Hippocratic author states it smells foul and requires boiling lest it produce a sore throat and coughing, perhaps reflecting putrefying from storage in reservoirs; Hellmann 1994, 275.

[56] *HN* 31.34–35: nam cisternas etiam medici confitentur inutiles alvo duritia faucibusque, etiam limi non aliis inesse plus aut animalium quae faciunt taedium (but cistern water even physicians admit is harmful to the bowels and throat because of its hardness, and no other water contains more slime or disgusting insects); trans. Jones 1963. Apparently not all doctors agreed: *HN* 31.31: eoque miror cisternarum ab aliquis [medicis] maxime probari (for this reason I am surprised that some physicians recommend highly water from cisterns); trans. Jones 1963.

[57] Columella, *Rust.* 1.5.2: quae tamen pluvialis aqua salubritati corporis est accommodatissima, sed ea sic habetur eximia, si fictilibus tubis in contectam cisternam deducitur (this rainwater is after all most suitable to the body's health, and is regarded as uncommonly good if it is conveyed through earthen pipes into a covered cistern); trans. Ash 1941.

[58] Ulpian, *Dig.* 43.22.1.4: nam cisterna non habet perpetuam causam nec vivam aquam (for a cistern does not have a perennial state or fresh water); trans. Watson 1985, as interpreted by White (1975, 133), who asserted Roman authorities believed "rain-water cisterns should only be used for human consumption in the last resort." The law code, however, may simply be contrasting permanent bodies of water versus those transient by nature.

[59] Arist., *Pol.* 1330b. Also, during the siege of Cirrha during the First Sacred War, Pausanias (10.37.7) says people resorted to drinking well and rainwater only after Solon diverted a channel flowing with river water away from the city.

bathing, preserving springwater for drinking.[60] Hellmann attributed these contradictions to an acquired awareness in ancient Mediterranean communities that cistern water could become unhealthy, despite its initial quality and frequent use.[61] If this is the case, we should perhaps view the two water systems at Pompeii as coexisting for different needs, or conceivably existing along a hierarchy of preference according to availability, given seasonal variations and longer-term climatic volatility, not to mention seismic events such as earthquakes and bradyseism that clearly impacted the water supply.

What proportion, then, of daily needs in Pompeii were provided for by the public fountains in relation to private cisterns? Given the inconsistency of evidence, there is no clear answer. If cistern supplies were ranked lower in quality after piped water, they could have been reserved for tasks apart from cooking and drinking, such as irrigating gardens, watering animals, cleaning, basic hygiene, and industrial uses.[62] This would have meant there was need to collect water from public fountains only for drinking and cooking.[63] On the other hand, units with inadequate or no cistern capacities must have needed more regular collection from public fountains to meet even these nonalimentary requirements.[64] Moreover, cisterns relied on regular rainfall. Extended periods of drought would have put more pressure on the piped water system as reserves were consumed.

An additional complication to modeling public water collection in Pompeii is the contribution of private piped water to daily household water requirements. Direct connections to the aqueduct system were relatively rare (approximately 9% of excavated units), certainly in comparison to the number of households with access to a cistern.[65] The purposes this piped water served within private homes also remains debatable. Detailed analyses have clearly demonstrated tap water was prioritized for luxury purposes such as fountain displays and private baths.[66] Direct connections to kitchens or latrines were extremely rare.[67] Without doubt the primary rationale for the installation of private waterlines was to signify the house owner's social status, and practical uses were tangential or incidental, at best.[68] Some have cautioned, however, that we should not overlook the probability that piped water served everyday domestic needs, too.[69] Many houses stored runoff from domestic fountains in cisterns, but this was not universal. Surprisingly, runoff was often directed into the street.[70] Even where it was stored, it was subject to the same contamination risks as rainwater, and often combined with it, compromising its advantages. Nevertheless, it would have been easier to access through a wellhead than via a vessel from a domestic fountain jet.[71] While we cannot omit the possibility that water was collected directly from

[60] Paus. 7.27.4: Pellene in Achaea.

[61] Hellman 1994, 273–75.

[62] Crouch (1993, 151–53) considered cisterns "subpotable," suitable for cleaning, irrigation, and animals. Similarly, Richardson (1988, 54): "wherever water of the quality of drinking water was not required." Thomas and Wilson (1994, 171) conversely asserted water stored in a dark, cool environment would remain potable through the dry summer months. In Dessales' (2013, 315–15) hierarchy, aqueduct water was reserved for fountains and baths, and cistern water for drinking.

[63] Crouch (1993, 33, 152). Cf. Richard (2012, 180–82), rejecting rigid divisions, arguing that only fountains satisfied the ancient preference for running water vis-à-vis cisterns and wells.

[64] See supra n. 47. E.g., cisterns in IX.3.13 and IX.3.8 were filled with refuse by 79 CE; neither had a piped connection; and IX.3.17 and IX.3.18 had neither cisterns nor pipes (E. Viitanen, pers. comm. 2021). Nonetheless, without a systematic private cistern survey, their exact distribution and capacities are uncertain. Certainly the 148 upper-floor apartments accessible via external stairs relied on public fountains alone.

[65] Supra n. 14.

[66] Andersson 1994; Jones and Robinson 2005; Schmölder-Veit 2009, 135–36; Leander Touati 2010, 122–26; Dessales 2013, 300–3.

[67] Jansen (2001, 40) noted only seven or eight houses with piped connections directly to kitchens and only two to latrines. Dessales (2013, 300) counted two kitchens and one latrine. These seem opportunistic rather than purposeful; i.e., pipes happen to run past kitchens on the way to baths; Schmölder-Veit 2009, 134.

[68] Aqueduct water was primarily installed in public reception areas (atria, peristyles, triclinia, baths) as showcases for the *dominus*; Dessales 2013, 301–3.

[69] Jansen 2001, 37; 2002, 55.

[70] In IX.3.5/24, piped water bypassed two cisterns (E. Viitanen, pers. comm. 2021). In insula V.1 (Leander Touati 2010, 125–26), cisterns collected some aqueduct runoff (e.g., V.1.3), but in the House of Caecilius Iucundus (V.1.26), a lead pipe bypasses the adjacent garden cistern, which was rainwater fed. Five drains led fountain runoff to the street here and in Casa del Torello (V.1.3.7). Schmölder-Veit (2009, 133) describes impluvia where adjoining cisterns were decommissioned after fountain installation, with runoff to the street. Jansen (2002, 49, 55, 57–58), however, presents capture of piped fountain runoff as standard in most houses, e.g., VII.12.28.

[71] As in Casa del Granduca (VII.4.56); Descoeudres and Sear 1987, 30.

private fountains for household use, most displays were not arranged for this objective.[72] If, however, this was done regularly, up to a quarter of Pompeii's population may have had access to privately available piped aqueduct water, since the largest units housed a greater proportion of the city's overall population, despite their smaller total numbers.[73] This is assuming aqueduct water was made available to all household members without restriction by social class, which is uncertain.[74] Nevertheless, private waterlines were present only in the largest and most opulent homes in Pompeii.[75] These households were the most likely to contain enslaved populations who could have been tasked with the labor intensive and unpleasant work of hauling water from public fountains. If a premium was placed upon aqueduct water's value for drinking and cooking, as suggested by some textual sources, then Pompeii's largest homes would have taken advantage of the publicly available water by choice rather than necessity, using household slave labor, as attested in literary sources. Moreover, with the interruption of private water connections across the city after the 62/63 CE earthquake(s), an increasing number of wealthy households would have been left only with a choice between the public fountains or cistern reserves.

## TEXTUAL SOURCES ON PUBLIC FOUNTAIN USE

References in Roman textual sources to fetching water from public fountains are frustratingly rare, presumably because this activity was so mundane it rarely warranted notice, except in exceptional circumstances such as shortages. Nonetheless, the limited information still sheds some light on the identity and social status of those who carried out this work and its perception among elite authors. A passing reference in Horace (*Sat.* 1.4.37–38), for example, alludes to two classes of people typically found about the city performing the usual daily errands of visiting a bakery and fetching water from the fountain (*lacus*): old women (*anus*) and enslaved males (*pueri*).[76]

One of the most descriptive scenes comes from Petronius' *Satyricon* (70.4–7) during the dinner with Trimalchio. Two enslaved men (*servi*) enter the dinner party carrying amphoras on their shoulders, having just returned from a fountain (*lacus*) where they were drunkenly fighting. Most likely the men were sent to fetch water from a public fountain, as the term *lacus* is almost exclusively employed with respect to public facilities.[77] Although Trimalchio's house has water features that could certainly signify a piped water connection, such as a bath (*balneum*) and a pool (*piscina*), nowhere is there an explicit reference to a domestic fountain that might be the drinking-water source for the party.[78] If this interpretation is correct, the passage supports the supposition that enslaved people collected water from public fountains for wealthy households.

Although appropriately absurd for satire, fighting at the fountain is in fact a recurrent literary theme occurring as far back as Old Comedy. In the *Lysistrata* (327–35), Aristophanes paints a vivid image of a mass of women at the fountain at dawn, both free and enslaved, pushing and shoving one another, clanging pots together, as they fill their vessels. It was not limited to satire and comedy, though. Libanius, in his oration in praise of Antioch (*Oration* 11.247), states that public fountains in many affluent cities of the empire were often scenes of turmoil—shouting, pushing, breaking of vessels, even physical violence (παγκρατιάζομεν:

[72] On the possibility of directly collecting water from private fountains, see Jansen 2002, 55. Andersson (1990, 218–20) noted fountains filled stone vases in Casas del Torello (V.1.3.7), dell'Efebo (I.7.11), and Paquius Proculus (I.7.1) that could have served both aesthetic and practical purposes. The 35 lead buckets found across Pompeii might have had similar functions. One sunk into the floor of Casa del Torello (*posticum*: Room d) near the latrine may have been used to collect runoff from a peristyle fountain for flushing or domestic manufacturing in nearby service rooms (Staub 2013, 52).

[73] The 113 units Jansen (2002, 82 n. 204) and Dessales (2013, 397–494) identified as likely having private water connections housed a maximum of 2,315 and minimum of 1,223 people, or about 26% of the population estimated for excavated zones of the city. For estimates of Pompeii's population, see below, "Household Water Requirements and Population."

[74] If piped water was valued, it may have been restricted to free members of the *familia*, leaving the enslaved to fetch water from public fountains or cisterns.

[75] Of these 113 units, 98 belonged to the fourth plot-size quartile; 14 belonged to the third quartile; only one unit belonged to the first quartile.

[76] On the dehumanizing use of *puer* (boy) for adult male slaves, see Edmondson 2011, 357–58.

[77] Dessales 2013, 54–55. Schmeling (2020, 210–11) translates *lacus* as "public fountain" here.

[78] *Piscina*: 72.7; *balneum*: 73.2–3. *Piscina* has a wide range of meanings in domestic contexts, but its occurrence in the *Satyricon* suggests a garden pool; see Dessales 2013, 58–59.

"we box and wrestle")—due to overcrowding.[79] While he is likely exaggerating in order to contrast the tranquil abundance of Antioch's water supply, this motif's frequency in other authors does suggest congestion was a problem in many large cities, especially when supplies were short. Crowding and violence at public fountains is a persistent theme in Late Antique sources that discuss damage to or maintenance of aqueducts or other supply issues.[80] In 562/3 CE, during Justinian's reign, chroniclers describe panicked thronging and even murders at Constantinople's fountains during a water shortage caused by drought.[81] Procopius (*Anecdota* 26.23) relays a similar occurrence earlier in his reign caused by damage to the aqueduct. A near identical situation is relayed by Choricius of Gaza at Caesarea in the early 530s CE.[82] The aqueduct's flow was reduced due to lack of maintenance, leading some fountains to dry out completely and others to have reduced streams. Fighting and pushing ensued between grown men, while "women, old men, and children came back, some with empty vessels; for some a great struggle produced half-filled ones to carry away, while many children went off crying because their vessels had broken."[83] These accounts underline how crucial public fountains were for urban populations and how their disruption could quickly foment panic and even violence. Even though no contemporary sources record these types of incidents at Pompeii, the damage and supply issues caused by earthquakes and bradyseism in advance of the Vesuvian eruption could well have produced similar outbreaks of social unrest.

Another important class of textual evidence for public water collection concerns the *aquarii* (water men), known from both literary and epigraphic sources.[84] The term seems to designate a number of occupations, ranging from imperial water administration (*cura aquarum*) personnel, to private water sellers or water carriers, or enslaved individuals tasked with similar duties in wealthy households, without clear delineations between usage.[85] Despite the frequent portrayal of *aquarii* as professional carriers who delivered water from public fountains into private homes, especially in large cities like Rome with multiple upper-floor apartments, this argument largely rests on analogy with medieval and early modern European cities where such professions were common.[86] While it is certainly possible that some *aquarii* known from inscriptions across the empire delivered water from public fountains for a fee, the term is unattested in Pompeii. A graffito from the Praedia of Julia Felix (II.4.10), however, mentions a *laguncularius* that could possibly refer to an individual who carried water in jugs or amphoras (*lago(e)nae / lagunculae*).[87]

Nonetheless the various *aquarii* had in common a very low position in the social hierarchy. They are classified in Diocletian's Price Edict among the lowest-paid unskilled laborers, just before sewer cleaners

[79] *Oration* 11.247: διόπερ οὐδὲ περὶ τάς δημοσίας παγκρατιάζομεν, ὅστις πρὸ τοῦ πλησίον ἀρύσεται, τοῦτο δὴ τὸ πολλὰς τῶν πολυχρύσων ένοχλοῦν· παρ᾽ οἷς ὠθισμός τε περὶ τὰς κρήνας καρτερὸς καὶ ἐπ᾽ἀγγείοις καταγνυμένοις ὀδυρμός καὶ πρὸς τοῖς κρουνοῖς τά τραύματα. ἡμῖν δὲ διὰ τὸ ἔισω θυρῶν ἑκάστοις εἶναι κρήνην αἱ κοιναὶ πρὸς ἐπίδειξιν ῥέουσι (So we have no free fights around our public fountains, as to who will draw water before his neighbor, which is a nuisance to many a wealthy town. There they push and jostle around the fountain, and there is weeping and wailing when bowls are broken and at the injuries received around the springs. We, however, all have our fountains inside our houses, and the public ones are for show); trans. Norman 2000.

[80] Lavan 2020, 243 and n. 54.

[81] Theophanes (*Anno Mundi* 6055) refers to two episodes: one in November 562 and another in August 563; Malalas, *Chronicle* 18.139, 18.147; see also Crow 2012, 129.

[82] Choricius, *Oration* 3.44–49 (*Panegyric for Stephanus*); Mayerson 1986.

[83] Choricius, *Oration* 3.46, trans. Mayerson 1986.

[84] E.g., Cic., *Fam.* 8.6.4; *Cod. Iust.* 11.43.10.4; Frontin., *Aq.* 2.110, 113–15; Rome: *CIL* 6 9131, 9145; *CIL* 9 3189 (Corfinium); *CIL* 9 460 (*collegium aquariorum* at Venusium); *CIL* 5 8307, 8308 = *ILS* 8321 (*aquatores* at Aquileia); *AÉpigr* 1964, 138 (public slave from Brundisium). Individuals designated as *aquarius Caesaris* (e.g., *CIL* 6 8491, 7973) certainly belonged to the *cura aquarum*.

[85] Bruun 1991, 108–9, 190–93; Dessales 2013, 273–74; Lamare 2020, 35–36.

[86] E.g., Stambaugh 1988, 131; Aldrete and Aldrete 2012, 184. Dessales and Bruun (supra n. 85) compare them to *acquaioli* in early modern Rome, Naples, and Venice, as well as artwork such as Jacopo del Conte's fountain in Rome, called Il Facchino, and Velazquez's painting *The Waterseller of Seville* (ca. 1620; Florence, Uffizi). On professional water carriers in medieval and early modern Europe: Davidson 1982, 7–21; Magnusson 2001, 138–44.

[87] *CIL* 4 10150; Peña 2007, 375 n. 50; Peña and McCallum 2009a, 64. The term could also signify a maker or a buyer or seller of vessels. Similar examples are known from Rome: *CIL* 6 9488 (*lagunara*); *CIL* 6 37807 (*negotians lagonaris*). See Peña 2007, 115–16.

(*cloacarii*).[88] Legal sources include them among the property inheritable from an estate along with other household slaves.[89] Frontinus characterized them as dishonest abusers responsible for fraud and waste in the water system.[90] In literature, the *aquarius* was a figure of ill repute often associated with prostitution. Juvenal ranked the *aquarius* a more shameful sexual partner for a woman than a slave.[91] Several sources identify the diminutive *aquarioli* (little water carriers) as servants who retrieved water for prostitutes at brothels, and Apuleius even used the term as an insult against his accuser in court.[92] Tertullian (*Apol.* 43) names them among a list of unsavory characters, including pimps, assassins, poisoners, magicians, soothsayers, and astrologers. One of the scandalous accusations lobbed against Commodus in the *Historia Augusta* is that he "carried water like a pimp's servant."[93] In Plautus, fetching water was presented as a form of backbreaking torture inflicted by one slave on another.[94] Even the above-mentioned graffito from Pompeii, if correctly interpreted, lists carrying water last among several, mainly unskilled, occupations, and ends with an emasculating sexual insult.[95] The totality of evidence presents an image of elite condescension toward individuals who carried water. In their view, it evoked servile associations (or worse), along with prostitution, social unrest, and official misconduct. This attitude surely reflects the strict class divisions that separated those whose water was provided to them by slaves and domestic water installations, and the common masses who had no choice but to labor for their daily water needs.

## THE GENDERED DIVISION OF WATER FETCHING?

Where Roman textual sources mention water carriers' gender, there is no clear pattern of labor division. Men, women, and children, both enslaved and free, all appear. Furthermore, *aquarius* is only attested in the masculine. Yet cross-culturally, women predominantly fulfilled water collection, especially in the premodern Mediterranean. Numerous anecdotes and literary motifs relate the cultural significance of women's morning routine of fetching water from a public source such as a well or fountain. In the Bible, for example, wells serve as a frequent meeting point for young women and male strangers, often resulting in marriage, as well as metaphors for female sexuality.[96] Similar associations are present in Ugaritic and Akkadian epics, as well.[97]

In the Greek world, both literary and visual evidence communicate the central role of water fetching to female identity. The scene from the *Lysistrata* (327–35) noted above is among the most emblematic. Daily trips to the fountain or well may have been some of the few opportunities Greek women had to leave the house unsupervised. Therefore, water sources may have served a pivotal role in women's social and public lives, offering independence and companionship while simultaneously reifying female domestic virtues.[98] In the *Homeric Hymn to Demeter* (98–110), for example, the goddess waits at a well for the daughters of Keleos to find her, knowing they will come alone to retrieve water. The Danaids' punishment represents a cruel perversion of typical women's labor. The literary evidence is corroborated by a common visual motif on Athenian pottery, mainly hydriai (water vessels),

---

[88] 7.31: Aquario omni die operanti pasto diurnos (denarios) biginti quinque (For an *aquarius* working all day, with food, 25 denarii). In Greek the profession is ὑδραγωγός; see Oleson 1984, 41–42.

[89] Paulus, *Sententiae* 3.6.58 (urban context); *Dig.* 33.7.12.42 (rural context).

[90] Frontin., *Aq.* 2.110, 113–15; see also Bruun 1997a, 138–39.

[91] Juv. 6.332. He further states that only an animal would be more appalling.

[92] Festus (20L) defines them as "the disgraceful servants of lewd women" (aquarioli dicebantur mulierum impudiarum sordidi adseculae). Apul., *Apol.* 78.1: "that little water-carrier of his own wife" (aquariolus iste uxoris suae) implying he prostituted her. On the association between prostitution and water supply: Cic., *Cael.* 34; Bruun 1997b; Butrica 1999; Berg 2018, 198–206.

[93] SHA, *Comm.* 2.9: aquam gessit ut lenonum minister.

[94] Plaut., *Cas.* 121–25: dabitur tibi amphora una et una semita, | fons unus, unum ahenum et octo dolia: | quae nisi erunt semper plena, ego te implebo flagris. | ita te aggerunda curuom aqua faciam probe | ut postilena possit ex te fieri (you'll be given one jug and one path, one spring, one copper pail, and eight vats. Unless they're constantly full, I'll fill you with lashes. I'll make you so properly stooped from carrying water that you could be turned into a crupper); trans. de Melo 2011.

[95] "si cunnu(m) linx<s>e<e>ris." As a slur, see Parker 1997, 51–53.

[96] Gen. 24:10–27, 29:1–11; Exod. 2:15–22; 1 Sam. 9:3–13; Prov. 5:15; Song of Sol. 4:15; John 4:1–26; Appler et al. 2020, 4–5.

[97] In the *Story of Aqhat*, Pughatu's epithet is "she who shoulders water" (Dietrich et al. 1995, KTU 1.19), while in the *Keret Epic*, the king's son meets his sister Thirmanat exiting the gate to draw water (KTU 1.16). In the *Epic of Gilgamesh* (1.141–74), the prostitute Shamhat seduces Enkidu by a water hole.

[98] Petersen 1997.

depicting women at the fountain house.[99] Women carry vessels on their heads identical to those on which the scenes are painted, though undecorated, and are seen filling them from a spout before returning home. Although debatable, they arguably represent scenes from Athenian women's daily lives, both enslaved and elite.[100] Women are seen socializing and working, occasionally with men, and sometimes even accosted by them, perhaps warning of the dangers of unaccompanied activity in the public sphere.[101]

Evidence for a similar gendered labor division in the Roman world is simply lacking. Nonetheless, there are hints in ritual and myth that suggest it may have been common in earlier eras, perhaps before slavery's growth shifted the burden by class rather than gender, at least within elite households. The Vestal Virgins, for example, continued to collect water for rites from the spring of Camenae/Egeria near the Porta Camena using a special ceramic vessel (*futtile*) that could not be set on the ground without spilling.[102] Another example involves a Vestal named Tuccia, accused of unchastity, ca. 230 BCE, who proved her innocence by carrying water from the Tiber to the forum in a sieve.[103] Mars' impregnation of Rhea Silvia, also a Vestal, though legendary, occurred as she fetched water from the Tiber in the morning, carrying a ceramic vessel on her head.[104] Some artistic representations include the vessel, but none depict it on her head.[105] Similarly, according to Propertius, the Vestal Tarpeia encountered Tatius while fetching water from a spring, shamefully dropping her vessel from her head.[106] Outside Rome and Latium, many Daunian stelae depict female figural processions with head-carried vessels, perhaps alluding to water collection in Iron Age Puglia.[107] Even if we conclude cultural norms of water collection shifted among the elite as a consequence of Roman imperialism, female responsibility may have persisted within more conservative subelite classes, which is less reflected in textual sources.

The Roman period, therefore, might be anomalous within a remarkably stable cultural tradition of female water collection in Italy. Medieval and early modern sources make clear it once again returned to a predominantly, though not exclusively, gendered task, with deep cultural reverberations.[108] The well or fountain again became the scene of romantic rendezvous for young women in popular culture.[109] A tradition attributed to the young Saint Rosa of Viterbo in the 13th century claims she miraculously mended a vessel that broke while she and her friends collected water from a fountain. Saint Catherine of Siena metaphorically related the daily dipping of women's vessels into the fountain to spiritual devotion. Also in Siena, reported attacks on women fetching water from extramural sources, among other factors, led the city to install fountains in more central locations throughout the 14th century.[110] By the 19th and into the mid 20th century, water collection in central Italian cities and villages was commonly managed by women carrying large bronze vessels, called variously *conca* or *tine* in different regions.[111] The primary mode of transportation was head-carrying using a wrapped cloth (*spara*) for padding. Although modern infrastructure has ended traditional practices, in several villages in Abruzzo women still carry *conche* in religious processions (*sfilate delle conche*), for instance at Guilmi in the region of Chieti, perhaps echoing the sustained fetching of springwater by the Vestals in antiquity long after numerous aqueducts supplied

[99] Predominantly black-figure, but examples in later red-figure are known, too. Similar scenes occur on amphoras and lekythoi.

[100] Bundrick 2019, 136–43.

[101] E.g., without incident, see Museo Gregoriano Etrusco Vaticano 16449 (*BAPD* 302871), acq. 1828–34; for harassed, see Brussels, Musées Royaux d'Art et d'Histoire R346 (*BAPD* 10964), acq. 1874.

[102] Plutarch, *Num.* 13.2; Serv., *ad Aen.* 11.339. The vessel has a wide mouth and narrow base, perhaps akin to a spiked amphora; see Edlund-Berry 2006, 164, 169.

[103] Dion. Hal., *Ant. Rom.* 2.69.1–3; Livy, *Per.* 20; Plin., *HN* 28.12; Val. Max. 8.1.5.

[104] Ov., *Fast.* 3.11–14: Silvia Vestalis (quid enim vetat inde moveri?) | sacra lavaturas mane petebat aquas. | ventum erat ad molli declivem tramite ripam: | ponitur e summa fictilis urna coma (Silvia the Vestal (for why not start from her?) went in the morning to fetch water to wash the holy things. When she had come to where the path ran gently down the sloping bank, she set down her earthenware pitcher from her head); trans. Frazer 1931.

[105] E.g., in a mosaic (Ostia, Caseggiato dei Doli near I.XIX) and the Igel funerary monument (Trier), she leans against a vessel flowing with water; see Gersht and Mucznik 1988.

[106] Prop. 4.4.15–16: hinc Tarpeia deae laticem libavit: at illi | urgebat medium fictilis urna caput (here Tarpeia drew water for her goddess; and an urn of earthenware pressed squarely on her head); trans. Goold 1990.

[107] Norman 2009.

[108] Davidson 1982, 7–21.

[109] Felice 1990, 78.

[110] Magnusson 2001, 29, 137–39.

[111] Felice 1990, 67, 77–79.

Rome.[112] Cultural norms of water carriage in the contemporary developing world are also being impacted by changing economic and social forces resulting from rural to urban migration, security concerns, the use of vehicles for transport, and sale by vendors. A recent analysis of more than two dozen contemporary global surveys found almost equal gender balance in specific regions, especially in urban contexts, despite its continued characterization as "traditional" women's work.[113] Nonetheless, women are still predominantly responsible in rural areas, where burdens are far greater.

## SOCIAL, ECONOMIC, AND HEALTH IMPACTS OF WATER FETCHING IN THE MODERN WORLD

Detailed documentation from later periods, as well as studies on water carriage in contemporary developing countries, provide useful points of comparison for parallel practices in Pompeii. They highlight numerous social and economic consequences for water carriers, as well as physical stresses, which are exacerbated in regions with inadequate resources or periodic supply shortages.

The United Nations and World Health Organization recommend individuals have access to 50 to 100 liters of water per day.[114] In communities without in-home water, this imposes significant burdens and often results in either the expenditure of substantial time per day collecting water or the consumption of lower than adequate quantities. On average, studies have found households without piped water spend about 30 minutes per trip fetching it, but local conditions result in wide variation between 10 and 65 minutes.[115] Crowding in some Kenyan cities, for example, leads to one to two hour delays to fill a vessel.[116] Single trip times, of course, must be multiplied by the number of individuals in the household and the fetcher's limits to bear heavy loads. One study of women in rural India found they carried 20 to 30 kg of water per trip (300 m, 6 to 7 minutes). However, this had to be repeated 22 times per day to collect enough for their household, resulting in totals of 132 to 154 minutes.[117] One to two hours per day spent fetching water is common in parts of sub-Saharan Africa and South Asia, rising to three to four hours a day during dry seasons. When time and distance become too burdensome, some households make do with as little as 10 liters or less per person, far below health and sanitation recommendations.[118] Furthermore, when the burden exceeds 30 minutes, it is more likely to be gendered labor assigned to women and female children, exacerbating social, economic, and health inequalities.[119]

Water insecurity and poverty often go hand in hand. Nearly half of impoverished women are afflicted by malnutrition and iron deficiency, which exacerbate the negative health effects of water carriage. In some rural regions of Africa and India, almost a third of women's daily energy is spent fetching water. These effects are worse when pregnant or nursing, and are linked to perinatal health complications.[120] Carrying heavy loads, especially in the traditional manner on the head, is associated with pain and musculoskeletal disorders such as cervical spondylosis resulting in neurological damage and spinal compression.[121] Pain-related disabilities often lead to water insufficiency since carriers are unable to travel greater distances or bear heavier loads.[122] Beyond direct health consequences, the burden of water collection feeds into social, mental health, and economic disparities. Walking long distances to fetch water exposes women to violence or leads to anxiety and stress over feared aggression.[123] Moreover, significant amounts of time fetching water mean less time devoted to wage-earning work and education, especially for children, which contributes to intergenerational poverty.[124] Distance and time to a water source are also associated with negative impacts upon children's health, such as gastrointestinal illnesses and infant mortality.[125]

---

[112] Consani 2001, 152–53; May 5 in honor of Madonna delle Grazie. Similar rituals occur in the province of Chieti at Dogliola, Palmoli, Celenza sul Trigno, Casacanditella, Altino, Lentella, and Roccascalegna.

[113] Geere and Cortobius 2017, 519–20, 522–23.

[114] UN Office of the High Commissioner for Human Rights 2010.

[115] Geere and Cortobius 2017, 520, 523.

[116] Ray 2007, 429.

[117] Sorenson et al. 2011, 1525; Sharma and Singh 2012.

[118] Ray 2007, 428–29.

[119] Graham et al. 2016.

[120] Sorenson et al. 2011, 1525; Geere et al. 2018, 14.

[121] Sharma and Singh 2012; Geere et al. 2018, 4–7, 21.

[122] Geere et al. 2018, 3–4.

[123] Sorenson et al. 2011, 1525; Geere et al. 2018, 8–14, 18.

[124] Ray 2007, 428–29; Graham et al. 2016; Geere and Cortobius 2017, 515.

[125] Geere et al. 2018, 2.

These findings resonate with historical reports from Italy before improvements to public water accessibility over the course of the 20th century. For example, long lines at public fountains to fill vessels were reported in central Italian villages. A parliamentary investigation published in 1909 found some women would fetch water at night to ensure their family's needs.[126] Historical records from elsewhere in Europe corroborate both ancient accounts of water collection from fountains and studies in contemporary developing countries. Records from cities in the British Isles in the 18th and 19th century report long queues of up to 50 people, sometimes lasting up to four hours, often resulting in arguments and brawls over fetching order at public wells and standpipes. After waiting over an hour, some women would leave to walk to more distant sources.[127] Not surprisingly, given these circumstances, urban consumption was very low. An 1850 survey in Scotland found residents used, at minimum, less than 4, and, at most, under 10 liters per individual per day. As a result, water usage was very conservative, with cleaning and even cooking and laundry sometimes ceasing altogether in the dry summer months.[128] Given these comparisons, it is clear that the placement and operability of Pompeii's public fountains had repercussions for day-to-day life and public health that far exceeded most other urban infrastructure design.

## A SPATIAL NETWORK ANALYSIS OF FOUNTAIN USE

### *Methodology: A 3D Street Network of Pompeii*

The spatial network model was analyzed in ArcGIS using layers adapted from the Pompeii Bibliography and Mapping Project (PBMP).[129] Fountains and doorways formed the nodes in this bimodal network, while the streets represented the ties or edges connecting them. Every exterior doorway in the city was plotted in a point layer while a second point layer located public fountains (fig. 5).[130] A polyline following the street network and crossing the forum was attached to each point feature to represent the network's edges. Since Pompeii is only about two-thirds excavated, the network remains incomplete, introducing some uncertainties near its interfaces with unexcavated zones. Projecting street extensions through these sectors is relatively straightforward, with few notable exceptions.[131] Missing, however, are an unknown number of additional buried fountains and doorways. Rather than hypothesize a doorway and fountain network in these zones, no projected nodes were included. Any data bordering on unexcavated areas are separated and treated with caution, cognizant that these are incomplete. The degree of uncertainty regarding the number and location of additional fountains, as well as the exact locations of buried doorways along street facades, would render an estimated model too speculative, while simply omitting these nodes within a complete street network minimizes imprecisions to undercounts for a small fountain subset.

The ArcGIS Closest Facility function, based on Dijkstra's algorithm, was used to identify least-cost paths from doorways to fountains.[132] In this way every doorway in the city is linked to its closest available fountain. Moreover, it incorporates the effect of Pompeii's natural topography on walking speed. Costs are derived in units of time (minutes) and metabolic energy consumption (kcals), which both vary with uphill versus downhill gradients. This represents a more sophisticated measurement of paths to fountains than simple linear distance. A digital elevation model (DEM) of Pompeii was created, from which elevation values were imported to each network segment endpoint to calculate its average gradient.[133]

### *Speed, Time, and Metabolic Energy*

Calculating the costs of traversing each network segment in minutes and calories requires a walking speed estimate that incorporates the effect of slope along the

[126] Felice 1990, 78.

[127] Davidson 1982, 11–12.

[128] See Davidson 1982, 15–20; 0.82 to 2.0 gallons per head per day.

[129] https://digitalhumanities.umass.edu/pbmp/.

[130] Total doors: 2,010.

[131] Poehler 2017a.

[132] The methodology follows Wernke 2012 and Wernke et al. 2017, with modifications. Although similar to least-cost analysis using accumulated cost surface rasters, this method is entirely vector-based, with costs derived from polyline attribute values.

[133] DEM based on a natural neighbor interpolation of 842 elevation points compiled by PBMP from: RICA maps of Pompeii (van der Poel 1984); Eschebach et al. 1993; Pompeii Archaeological Research Project: Porta Stabia; and research on Tower Nine. See https://arcg.is/1a8myi. The polyline edge network was segmented into 3 m sections using a customized version of Higgins (2019) ArcGIS Python tool that calculates times based on additional equations and energy costs in calories (https://github.com/mnotarian/3D_Network_Toolbox).

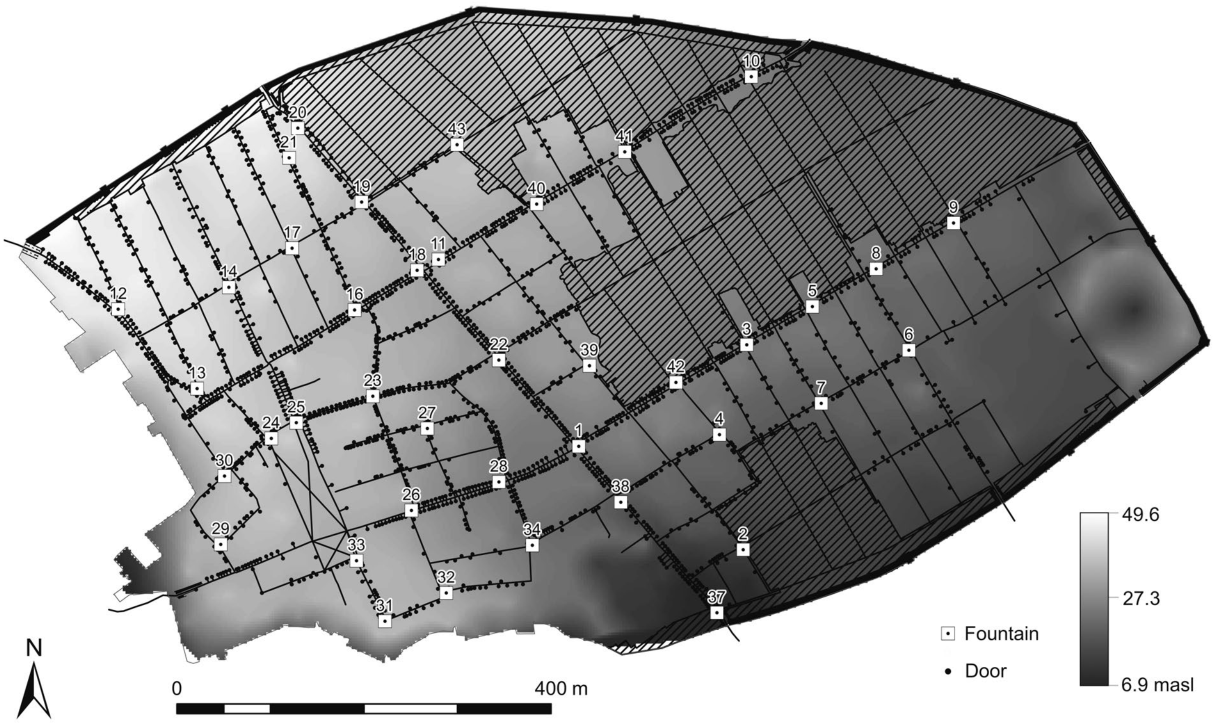


FIG. 5. Fountain–door network overlaid on a digital elevation model of Pompeii.

street network. Among the various proposed functions for predicting walking velocity (online fig. 1), Márquez-Pérez et al. (hereafter MP), a corrected form of Tobler's Hiking Function, predicts a maximum speed of 4.8 kilometers per hour at a slight downhill grade, which slows with greater gradient in either direction.[134] A study of female water fetchers in rural India, however, recorded walking speeds, on average, between 3.1 and 3.5 kilometers per hour while carrying loads of 20 to 25 kg over 300 m on relatively flat ground, speeds that only occur on higher slopes in the above equations.[135] For this reason, a modified version of Tobler's equation (MT) was also formulated with a 3.5 kilometers per hour maximum speed. Unfortunately, there is not enough available empirical data on water carrier walking speed to conclude how typical these results are. MP and MT represent fast and slow speeds in the model, respectively.

Costs in minutes ($T$) were solved using equation (1), where $L$ is the 3D length of the network segment and $V$ is walking speed in kilometers per hour.

$$T = \left(\frac{L}{V(1000)}\right)60 \qquad (1)$$

Climbing stairs to an upper-floor apartment added additional time, but walking equations cannot estimate stair climbing.[136] Empirical studies of stair climbing speeds, on the other hand, find average speeds between 1.4 and 2.0 kilometers per hour for individuals of various ages and genders.[137] The stair length of a typical upper unit from Herculaneum (IV.20), where preservation makes this calculation possible, would result in a round-trip time of around 30 seconds, which was added to every upper-floor unit in the model.

Calculating costs in calories has two advantages. Like minutes, it offers an intuitive unit of measurement, but additionally situates water-fetching labor with respect to daily dietary requirements. Metabolic energy was calculated using the Pandolf load carriage

[134] Márquez-Pérez et al. 2017; Tobler 1993. Online figures available at https://doi.org/10.1086/722233.

[135] Sharma and Singh 2012. Time is recorded as faster on the return journey, likely due to the heavy load.

[136] Comparison of the catalogues in Pirson 1999, Flohr 2018, and Eschebach et al. 1993 yielded 148 upper-floor apartments.

[137] Choi et al. 2014, with references.

equation with a correction factor for negative gradients proposed by Santee et al.[138] The caloric costs of stair climbing with a load also require an additional calculation. The Compendium of Physical Activities includes estimated metabolic equivalents for climbing and descending stairs with varying loads.[139] These were used to calculate calories for a 65 kg individual climbing upstairs with full loads and downstairs with empty loads of different weights. A more detailed explanation of these methods is included in the online appendix.

*Vessel Sizes, Forms, and Weights*

The size of the collecting vessel is a crucial variable. It determines the daily number of required trips per household to provide the requisite amount of water per capita. There is an inverse relationship between vessel size and required trips. Larger vessels resulted in fewer trips to the fountain as these retrieved more water, however, their heavier weight rendered the labor more arduous. For individuals, the choice must have been a balance between efficiency and exertion whether to carry a larger heavier vessel to minimize trips, or to spend more time each day carrying smaller and lighter loads (online fig. 2).

Textual sources mention various vessel names for fetching water. Petronius and Plautus call them amphoras, though the latter specifies bronze (*ahenum*).[140] Other sources that explicitly discuss fountain collection, such as Libanius, unfortunately use generic terms for ceramic vessels (e.g., ἀγγεῖον).[141] Nonetheless, there are numerous references to vessels that held water in a variety of contexts, including *cadus*, *lagoena*, *vas*, *urceus*, *urna*, *situla*, and *hama*, sometimes paired with the adjective *aquarius*, or the substantive *aquarium* used independently.[142] A graffito scratched into a domestic fountain in the House of Neptune and Amphitrite in Herculaneum (*CIL* 4 10566) lists various household items, including three types of water vessels: *hamas cum basis* (water buckets with bases), *aquaria cum basis* (water jugs with bases), and *aquaria in manus cum basis* (*cotidian[a]*) (hand[-sized?] water jugs [for daily use]).[143] Though tempting to connect to water fetching, applying these terms to archaeological forms is problematic.[144] Some are commonly identified as buckets (*hama, situla*) but the others surely referred to various jugs or pitchers with or without handles.

The term *amphora*, on the other hand, is confidently connected to numerous two-handled vessels that bear this attribution today. They occur, however, in wide size varieties, and it can be difficult to discern the reuse of wine amphoras from purpose-made water vessels in written sources. Visual evidence may support amphora use, either primary or secondary, as water containers, though none with explicit reference to fountain collection. Perhaps the most straightforward example is the so-called silver patera of Otañes from Castro Urdiales, Spain, connected to a mineral spring associated with Salus Umeritana. Amid various figures related to its religious and healing qualities is a man filling a cask wagon from a large narrow amphora, certainly containing springwater, to be distributed or sold for drinking.[145] A similar scene occurs on the funerary relief of Q. Veiquasius Optatus from Cherasco, Italy, but this has variously been interpreted as containing either springwater or wine.[146] Interestingly, however, the scene is flanked by a series of eight female figures, four dressed in short tied-up tunics typical of barmaids and working women, carrying vessels either on their shoulders or heads that evoke water carriage.[147] A terracotta relief from Isola Sacra near Ostia, showing a vendor in a shop full of amphoras, has been interpreted as a water seller due to his name, Lucifer Aquatarius.[148] Images of servants or slaves pouring liquids from amphoras are also equally difficult to interpret as either water or wine. However, a painting from Villa Farnesina cubiculum B, along with an analogous mosaic from Centocelle, showing a woman pouring liquid into a silver basin beside an intimate scene of a man and woman,

[138] Pandolf et al. 1977; Santee et al. 2003.

[139] Ainsworth et al. 2011.

[140] Petron., *Sat.* 70.4–5; Plaut., *Cas.* 121–22.

[141] However, Plutarch (*Vit. Rom.* 20.6) uses the term in reference to vessels carrying water for a sacred tree.

[142] White 1975, 127–30, 150–51, 161–64, 188–90, 194–200, 202–4; Peña 2007, 133.

[143] Benefiel et al. 2016, 14.

[144] Mustaţă 2011.

[145] Peña 2007, 134–35.

[146] For wine: Berg 2019, 219 n. 63. For water: Thomas and Wilson 1994, 157 n. 72. The deceased's description as *sacrorum cultor* may allude to a religious position, perhaps strengthening the association with sacred water versus wine.

[147] Berg (2019, 219 n. 63) compares them to the hydriai the Danaids carry.

[148] Jansen 2002, 135–36; Dessales 2013, 245; Ellis 2018, 236–37. Bruun (1991, 109) notes *aquatarius* is unattested either as a cognomen or a profession, leaving its interpretation in doubt.

recall the recurrence of water basins and jugs in other erotic imagery.[149] A clearer example is perhaps the mosaic from Oued Ramel in Tunisia, which shows a man pouring water from an amphora on his shoulder to be mixed with lime in preparing mortar.[150]

Archaeological context may also hint at specific forms that were used for water transport, but this is likewise difficult to prove conclusively. For example, a Dressel 1B amphora found in a pit of a Pompeian lamp workshop (I.20.2–3) may have been used to carry water from a cistern to prepare clay, but only if the feature was not a cesspit. Numerous Dressel 2-4s were also stored in Room 4 near the cistern wellhead.[151] Allison's artifact assemblage analysis in Pompeii's insula I.10 identified various amphoras, buckets, and small bronze jugs found in proximity to puteals.[152] Yet the size and weight of typical Pompeian transport amphoras, such as Dressel 2-4s, present serious impediments for public water fetching. Varying between 91 and 109 cm long, they could not be dipped perpendicularly into any extant public fountain basins.[153] Even tipped horizontally, they would only fit in some larger basins and would extend nearly across their entire length. Furthermore, they weigh 12 to 14 kg empty and 40 to 42 kg full of water, much heavier than any weights identified in contemporary water-fetching studies, and likely beyond the physical abilities of many water carriers over longer distances through the streets.[154] More promising is Peña's interpretation of numerous smaller flat-footed table amphoras found in Athenian wells. Several forms had holes punched in their shoulders for repurposing as water-fetching containers.[155] Amphoras with similar holes in their necks or bellies were found in Pompeii, but these were probably made to extract goods stored within them.[156] Unfortunately, no data has been published from Pompeian wells excavated down to use levels in which comparanda might be found. However, a very widespread class of locally produced table amphoras, commonly found in domestic contexts including kitchens, is not unlike the forms from the agora wells.[157] These are a smaller flat-footed Dressel 2-4 variant with an average capacity around 17 liters, weighing about 7 kg empty, and only 63 cm long.[158] Full of water they would weigh about 24 kg, which is within the upper range of comparative evidence. They also have a higher center of gravity, closer to the handles, that may have made them considerably easier to shoulder-carry than their larger cousins.[159]

Comparison with vessels from other periods suggests even smaller forms may have been preferred. Many undecorated hydriai from the Athenian agora, for example, have a capacity of only 9 to 11 liters.[160] The *conche* that women carried in early modern Italy consisted of two varieties of about 10 and 20 liters.[161] The Indian study referenced earlier found that women carry loads between 20 and 30 kg per trip, which also includes the container weight. The researchers concluded that 15 kg loads were the most appropriate to avoid injuries while head carrying.[162] An archaeological experiment at Tel Jezreel in Israel determined women carried between 6 and 8 liters per trip.[163]

Since no Pompeian forms can be confidently linked to long-distance water transport, the model compares a series of theoretical ceramic vessels of varying sizes (table 1). The empty to full weight ratio was approximated using that of the flat-footed Dressel 2-4 (about 1:2.4, rounded to whole digits).

*Household Water Requirements and Population*

Estimating individual households' daily water requirements necessitates an approximation of how many people lived within each unit. A unit is defined

[149] Lund (2011) discusses various visual depictions of amphoras. On sex and water: Berg 2018, 198–99.

[150] Peña 2007, 133–34.

[151] Peña 2007, 135–36; Peña and McCallum 2009a, 64–70.

[152] Allison 2006, 361–62, 377–80.

[153] The deepest fountains were 92 cm (online appx. table 3). For Dressel 2-4 measurements, see Muslin 2019, 186.

[154] Avg. capacity is 28.6 liters: Molina Vidal and Mateo Corredor 2018, 304. For the empty weight: Muslin forthcoming.

[155] Peña 2007, 136–38. Forms include Late Roman 3 types (average capacity 5.6 liters), Keay 52 (capacity ca. 7.0 liters), and smaller unidentified vessels between 28 and 30 cm tall.

[156] Peña 2007, 68–69.

[157] E.g., Room 11 in Casa del Fabbro (I.9.7) before the hearth (Allison 2006, 192, no. 1365).

[158] Panella and Fano 1977, 151 n. 15; Peña and McCallum 2009b, 179; Molina Vidal and Mateo Corredor 2018, 304; Muslin 2019, 357–58.

[159] Muslin 2019, 187–88, 193–94.

[160] E.g., object nos. P18986 (hydria, 425–400 BCE, 9.0 liters) and P24128 (Chiote hydria, 520–490 BCE, 11.5 liters). Volumes calculated using the Centre de Recherches en Archéologie et Patrimoine, Université libre de Bruxelles web applet: https://capacity.ulb.be/index.php/en/research-center-in-archeology-and-heritage/.

[161] Consani 2001, 152.

[162] Sharma and Singh 2012.

[163] Appler et al. 2020, 14.

TABLE 1. Vessel parameters used in the model.

| Capacity (liters) | Empty Weight (kg) | Full Weight (kg) |
|---|---|---|
| 20 | 8 | 28 |
| 17 | 7 | 24 |
| 15 | 6 | 21 |
| 13 | 5 | 13 |
| 10 | 4 | 14 |
| 7 | 3 | 10 |
| 5 | 2 | 7 |

as any internally interconnected set of rooms with at least one external door, including purely domestic as well as commercial and industrial spaces, since many doubled as living spaces. External doors with stairs to upper-floor apartments are also counted as single units. Pompeii's population remains a contentious topic, and there is no need to reiterate various arguments here.[164] Nonetheless, a brief methodological explanation is warranted. The principal obstacles to using a simple measure, such as people per square meter, are large properties that include considerable agricultural and garden space, which would allocate too many people by plot size alone. Methods that assign specific inhabitant numbers per functional unit category, on the other hand, do not reflect variation in population between large elite houses, that must have housed various dependents in addition to the owner's biological family, and small houses, which did not. These methods also spread population around the city evenly, negating high and low population clusters that certainly existed. Rather, for this model, a method was needed that would reflect this variation and its effects on fountain usage in different zones. Therefore, maximum and minimum unit populations were estimated using the number of ground-floor rooms in each unit, after Flohr's recent methodology (table 2).[165] For upper-floor apartments, a set maximum and minimum population was used, since second-story rooms are not preserved. Differences in the data sets required minor adjustments to preserve the total population.[166]

The total household water requirement is a simple multiplication of unit population by the quantity per capita, but this figure needs to factor in the availability of private cisterns, domestic fountains, and public baths, as discussed earlier. The United Nations recommendation of 50 to 100 liters daily per capita is likely too high since this includes water for sanitation and other purposes beyond cooking and drinking. The World Health Organization considers 7.5 liters daily per capita to be a short-term emergency minimum, while 20 liters per capita is acceptable for most basic needs, if not ideal. If we assume water collected from public fountains at Pompeii represented some fraction of total water requirements, such as water for cooking and drinking, low and high estimates of 10 and 20 liters daily per capita would likely be in the right order of magnitude. For some units, such as upper-floor apartments and tabernae without access to a cistern, this is probably too conservative, but it nonetheless provides a reasonable baseline for estimating fountain usage across the city.

*Model Parameters and the Number of Round Trips per Day*

The current model assumes 40 fountains were functional in 79 CE, the period most clearly represented in unit divisions based on extant architecture. This omits the two fountains in the Triangular Forum and quadriporticus; in both areas, street fountains probably served nearby households. The fountain basins in the Arch of Caligula are also excluded since these were certainly removed by this date, as were the three fountains in the forum.

The Closest Facility analysis was run twice to calculate round trip totals. The first iteration searched for least-cost routes from fountains to units since, hypothetically, this would be the more difficult trip. Loaded with a heavy vessel, carriers would likely avoid uphill journeys in this direction. The analysis was then run a second time in the opposite direction to model times

[164] Flohr (2017, 56–62) summarized the main issues, although the inscription discovered in 2017 outside Porta Stabia (*AÉpigr* 2018, 498) has reignited debate. This study maintains a population in the range of 7,000–12,000 people.

[165] Flohr 2017, 60–68.

[166] Flohr's map (2018) was based on Eschebach et al. (1993), while PBMP used RICA maps (van der Poel 1984), resulting in different unit and room counts. Flohr also developed a functional unit typology, whereas PBMP uses Eschebach et al. Though Flohr's figures for people per rooms were used, I rounded up each unit population before summing, whereas Flohr rounded up the sums only.

TABLE 2. Pompeii population estimate.

| Unit Type | People per Room (max / min) | Room Count | Maximum[a] | Minimum[a] |
|---|---|---|---|---|
| **Extant Architecture** | | | | |
| Taberna | 1.43 / 0.80 | 771 | 1,287 | 740 |
| All other | 0.75 / 0.48 | 9,139 | 7,117 | 4,716 |
| | People per Unit (max / min) | Unit Count | Maximum | Minimum |
| Apartments | 5 / 2 | 148 | 740 | 296 |
| Total | – | – | 9,144 | 5,752 |
| **Estimate for Unexcavated Zones[b]** | | | | |
| Unit Type | People per Room (max / min) | Room Count | Maximum | Minimum |
| Taberna | 1.43 / 0.80 | 197 | 282 | 158 |
| All other | 0.75 / 0.48 | 3,194 | 2,396 | 1,534 |
| | People per Unit (max / min) | Unit Count | Maximum | Minimum |
| Apartments | 5 / 2 | 7 | 35 | 14 |
| Total | – | 3,391 | 2,713 | 1,706 |
| Grand total | – | – | 11,853 | 7,453 |

[a] Each unit population rounded up before summing.
[b] Based on Flohr 2017.

and energy anisotropically. The corresponding unit–fountain pairs were tallied to produce round-trip totals. For energy, calories were summed so the empty vessel weight was applied in the outbound trip while the full vessel weight was used in the return.

The number of trips per day by unit was determined by multiplying both population estimates by 10 and 20 liters, respectively, then dividing by the carrying vessel's capacity. Total time and energy per day spent fetching water per unit could then be calculated by multiplying the number of trips by the single round-trip values.

## RESULTS AND DISCUSSION

### *The Effect of Velocity and Load-Bearing on Routes and Connections*

The Closest Facility analysis was solved using several different costs in time and energy as impedances and the results compared. Between the fast (MP) and slow (MT) times, the chosen fountains were nearly identical, with only three out of 2,010 door-to-fountain paths differing. Only slightly more differences occur comparing calories as costs, indicating an incrementally larger load bearing effect. There were 23 different routes solved carrying the heaviest (28 kg) compared to the lightest (7 kg) load at MP pace. This only results in 13 different unit–fountain connections, a mere 1% of the total. Comparing time and energy impedances, however, results in greater discrepancies of 6–7%. Most of these doorways are in medially distant zones between fountains, underlining the narrow cutoffs between one choice and another in these liminal areas. Almost a third, however, cluster along Via Stabiana between Vicolo del Conciapelle and the unnamed *vicolo* between insulae I.2 and I.3, as well as along the latter. Vessel size played a greater role in the choice of fountain given the steepest gradients in the city. We can therefore imagine more blending of social networks here as users likely circulated between fountains 2, 4, 37, and 38 more indiscriminately. Overall, however, most generated fountain districts are stable using different impedances and vary primarily in cost quantities at different speeds and loads. For the following analysis, the district composition was determined using the shortest walking times as predicted by MP.

*Fountain Districts: Single- or Multiple-Fountain Communities*

The process of connecting every external door in Pompeii to its nearest fountain revealed that fountain selection, and the districts or neighborhoods thereby defined, was far more complex than previously understood. As many units have more than one entrance, the closest fountain depended on the door exited. Furthermore, only a few seconds of additional time often separated the closest from more distant options. One can question whether water carriers even perceived or considered such minor differences. Individual agency must have played a significant role in neighborhood composition.

For the present study, two methods were used to determine the boundaries of fountain catchment areas or neighborhoods. The first connected each unit to the single closest fountain via the absolute least-cost connection of every unit doorway (fig. 6). This represents the most rational fountain choice and heuristically reduces the complexity of a network of individual agents down to a singular model for further analysis. As with any model, it does not necessarily represent the exact fountain a particular unit used on any given day, but it represents a distinct set of parameters. The second method acknowledges increased complexity by connecting units to each fountain reached by a least-cost path from any of its doorways (fig. 7). While most units (93%) still only connect to a single fountain, the presence of side or back doors linked some units to two or even three. Not surprisingly, these included the largest homes in the city with multiple entrances facing opposite insula sides, such as the House of the Faun (VI.12.2) and the House of the Citharist (I.4.5). Smaller units appear, too, thanks to their liminal location, such as the three-room shop with two doors at VIII.5.18–19 that is about halfway between fountains 26 and 28. Collectively, these units represent the fluid boundaries between core communities of fountain users—those who were likely to select a different water source on any given day. In terms of the water fetcher social network, these individuals constituted vital interconnections between static consumers who habitually frequented a single water source. Although the topic deserves further scrutiny, this study only considers the single closest fountain to each unit in the following analysis. With the multiple-door method, units and their populations would be counted two or three times for each linked fountain in the quantifications below.

District size varies widely according to the relative fountain clustering. The count of units each fountain served, however, is a more significant figure, since this determined the number of people who depended on it (fig. 8). Partitioning these counts into PBMP's functional unit typologies (based on Eschebach's catalogue) reveals different district characteristics, such as the balance of commercial versus residential users in each (fig. 9). Unit typologies, however, are debatable and prone to circular reasoning.[167] Moreover, many units share multiple functions, so this count is larger than the raw count of units alone. A more objective classification is plot size quartiles, which has long precedent in studies of the Vesuvian cities (fig. 10).[168] Although imperfect, these categories capture fundamental differences in socioeconomic class between small, medium, and large properties. While all water fetchers likely belonged to subelite groups (e.g., slaves, freedpeople, freeborn poor), we can perhaps further characterize their composition accordingly. For instance, the fourth quartile, representing the largest elite units in Pompeii, probably tasked enslaved household members to fetch water. The first and second quartiles, including residents of one- or two-room shops and upper apartments, most likely were composed of low social status, nonslaveowning free and freed residents, among whom perhaps women continued to serve as primary water collectors.[169] Furthermore, properties in the fourth quartile required a greater expenditure of time and energy to supply their higher populations, but multiple people may have accomplished these tasks, whereas those in the first quartile probably relied on a single water carrier.

There is wide variation in the number of units (excluding public buildings) each fountain served, ranging from a minimum of seven to a maximum of 72. This may explain why the fountains are not a standard size across the city but instead cluster around three different volumes, supporting the expected differential consumption.[170] There is a moderate but statistically significant positive correlation between basin volume and the number of units served (fig. 11; online fig. 3). Some fountains, however, like number 23, were clearly

[167] Kaiser 2011, 74–76; Ellis 2018, 35–36.

[168] Wallace-Hadrill 1994; Robinson 1997.

[169] Upper-level apartments have no plot size since their extent cannot be determined.

[170] See supra n. 26; patterns, however, are not as straightforward as characterized by Schmölder-Veit (2009, 128).

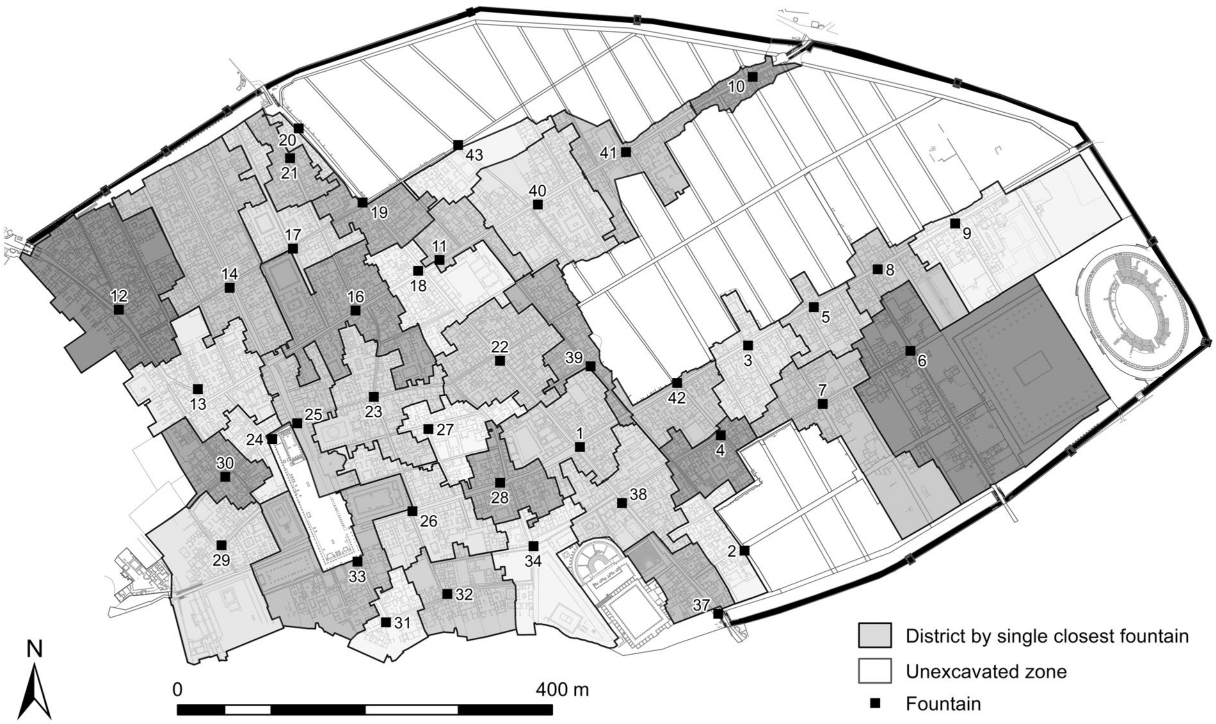


FIG. 6. Districts by single closest fountain (varied shades of gray are used to make the districts discernable).

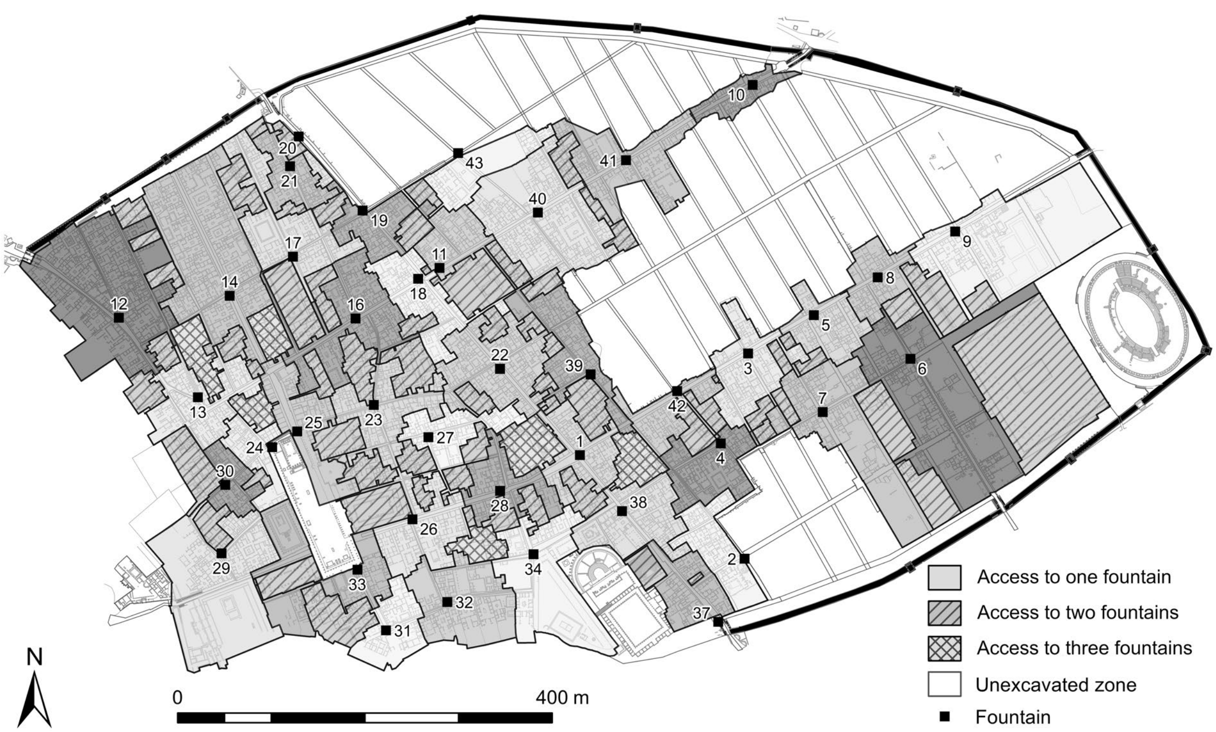


FIG. 7. Districts by closest fountain from any external unit door. Multifountain districts consist of units with multiple external doors whose least-cost paths connect to different fountains (varied shades of gray are used to make the districts discernable).

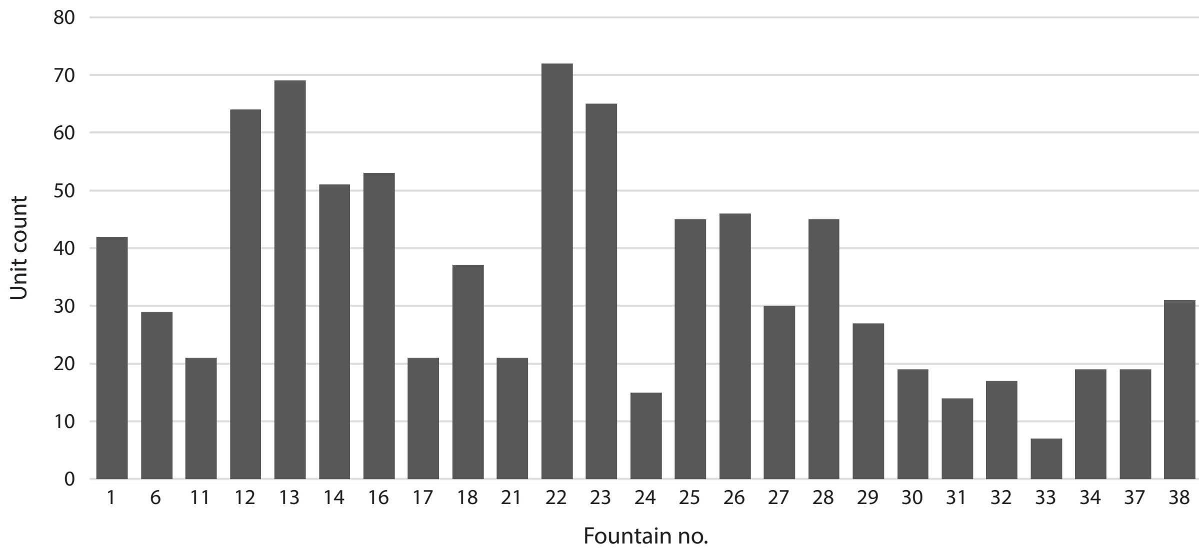


FIG. 8. Count of units by fountain district (incomplete districts are excluded).

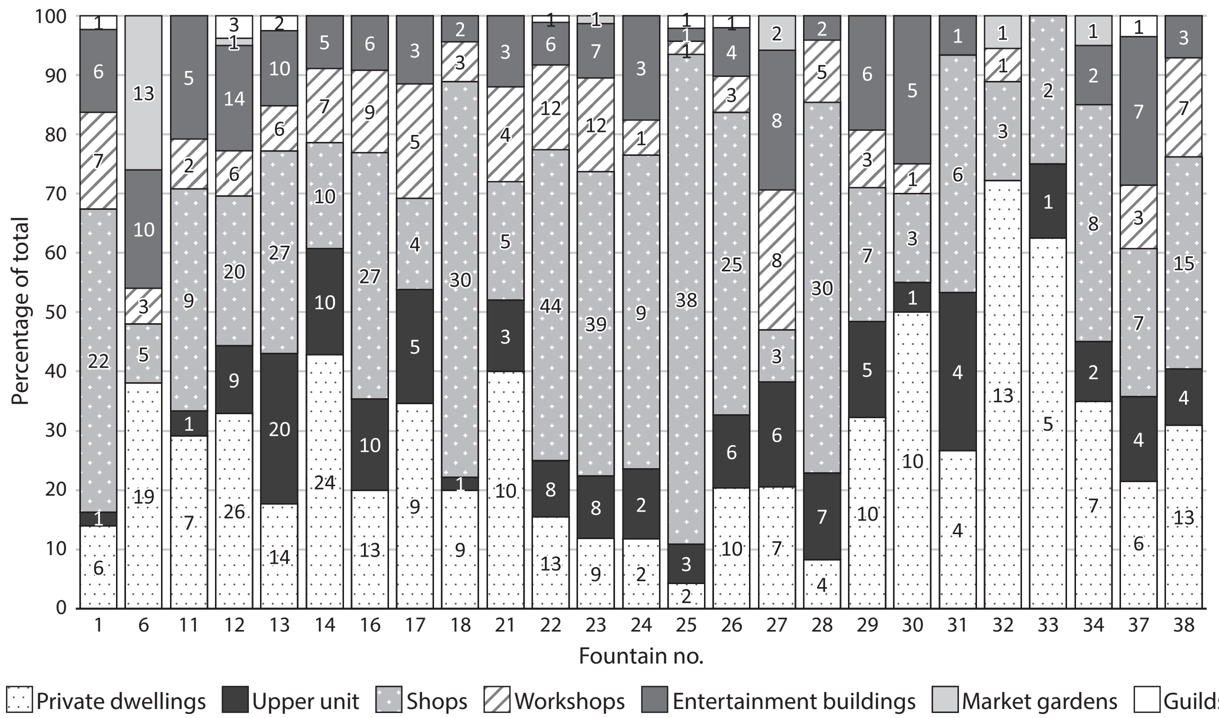


FIG. 9. District composition by unit function (incomplete districts are excluded). Inset numerals indicate unit count.

overworked, while the two largest fountains (1 and 26) were underutilized. While not a perfect relationship, there is no similar correlation between fountain size and other data, such as population served or district area, suggesting basin volume was consciously planned to facilitate the number of units served. The presence of outliers may be explained by changes in property divisions after the system's initial planning in the Augustan era, or problems locating fountains due to external factors, such as elevation or pipeline proximity. They could also simply reveal a poorly managed system that reactively adjusted to systemic pressures via inadequate or haphazard modifications, perhaps by private benefaction.

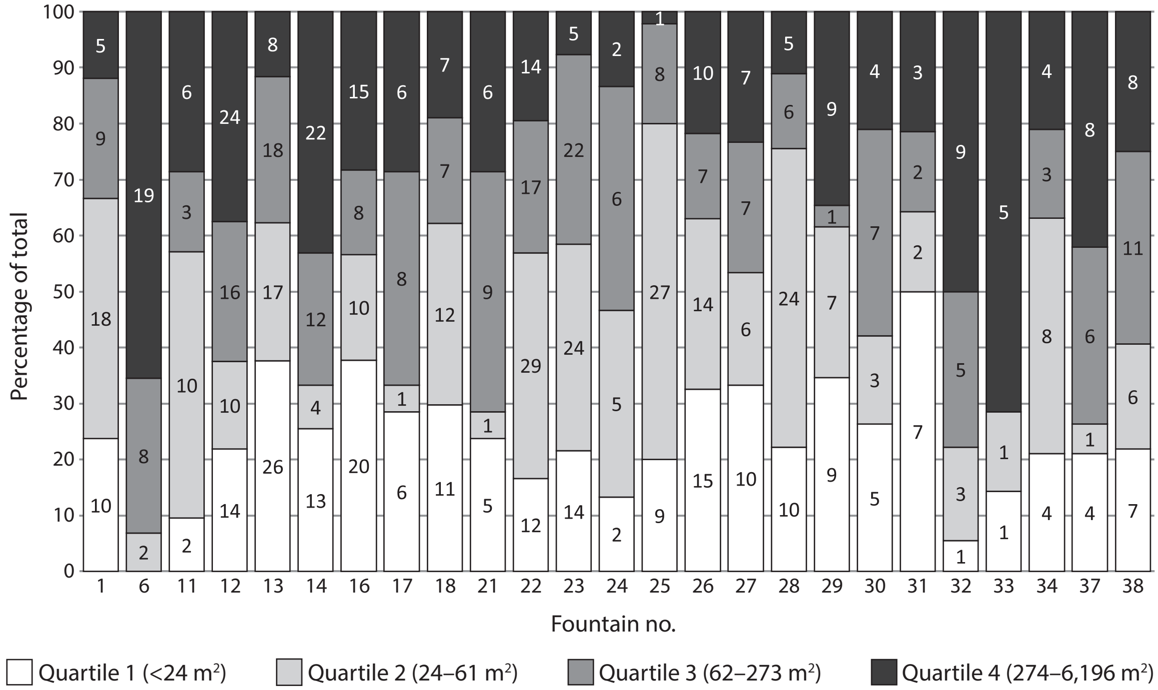


FIG. 10. District composition by plot-size quartile (incomplete districts are excluded). Inset numerals indicate unit count.

The district unit count, however, only partially characterizes fountain utilization since it does not differentiate between widely varying household sizes. Minimum and maximum unit population figures provide the best estimate of differential usage throughout the city and indicate where crowding and supply shortages likely occurred (fig. 12). Most fountains exceed Eschebach's estimate of 160 people per fountain, even at the minimum range, and this underscores how fountain distribution did not eliminate overcrowding and underutilization at specific locations.[171] The total population per fountain can also be multiplied by per capita water requirements to estimate the quantity of water needed to meet demand. Although fountain flow rate remains debatable, a recent study proposed an intermediate average of 0.43 liters per second, which provides a baseline to measure the quantity delivered in comparison to need.[172] A rough approximation divides the total daily district requirement by the volume of the fountain basin to arrive at the number of full basins needed per day. Using the proposed flow rate, estimates are calculated for the time needed

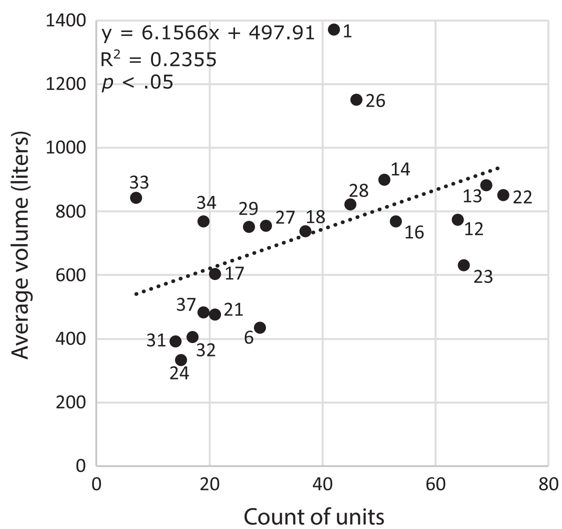


FIG. 11. Relationship of basin volume to count of units served. Numerals identify the fountain number (incomplete fountain districts are excluded).

to fill them with these quantities (fig. 13). In reality, more time would have been necessary since the basins could only have been used for dipping provided they contained enough reserve to submerge a vessel. Nonetheless, these calculations already indicate the busiest fountains, 12 and 14, would have required 5 to 8 hours to deliver the total water quantity at 20 liters per capita

[171] Eschebach 1979, 11.
[172] Monteleone et al. 2021. The minimum average (0.08 liters per second) would result in much longer times.

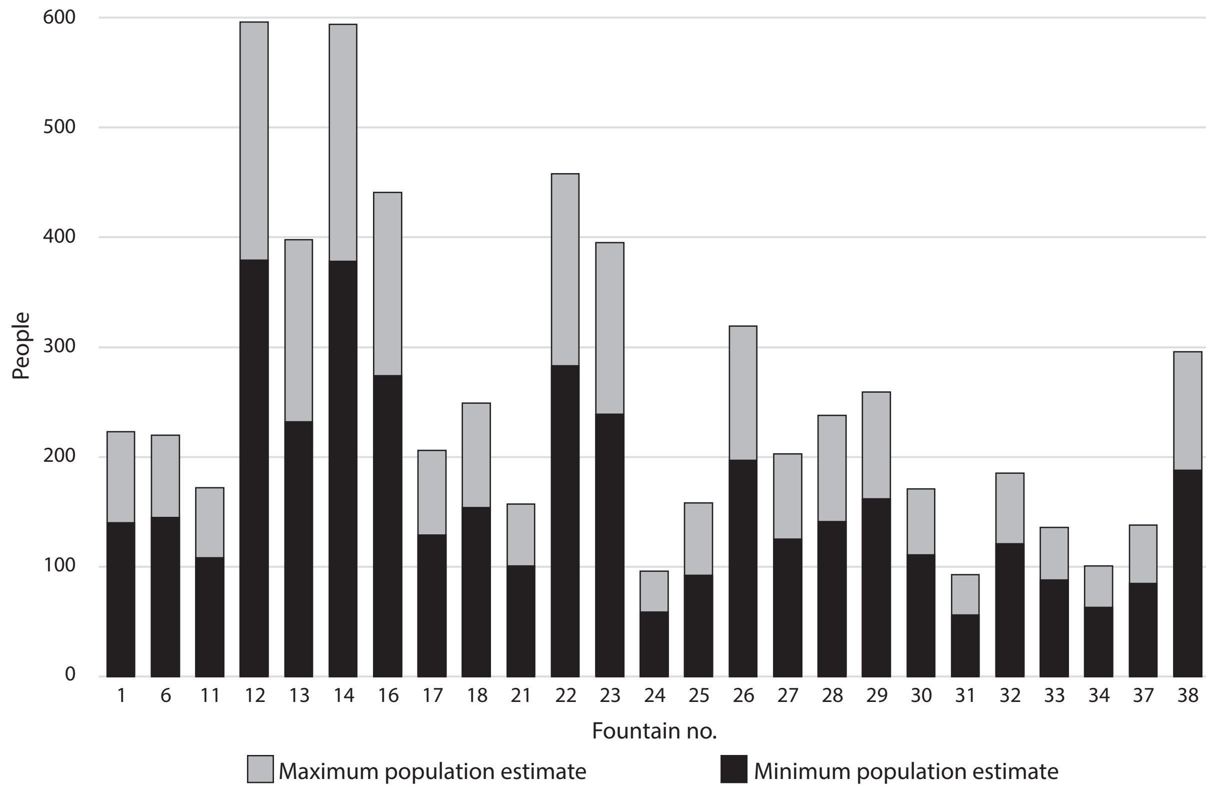


FIG. 12. Population served by fountain (incomplete districts are excluded).

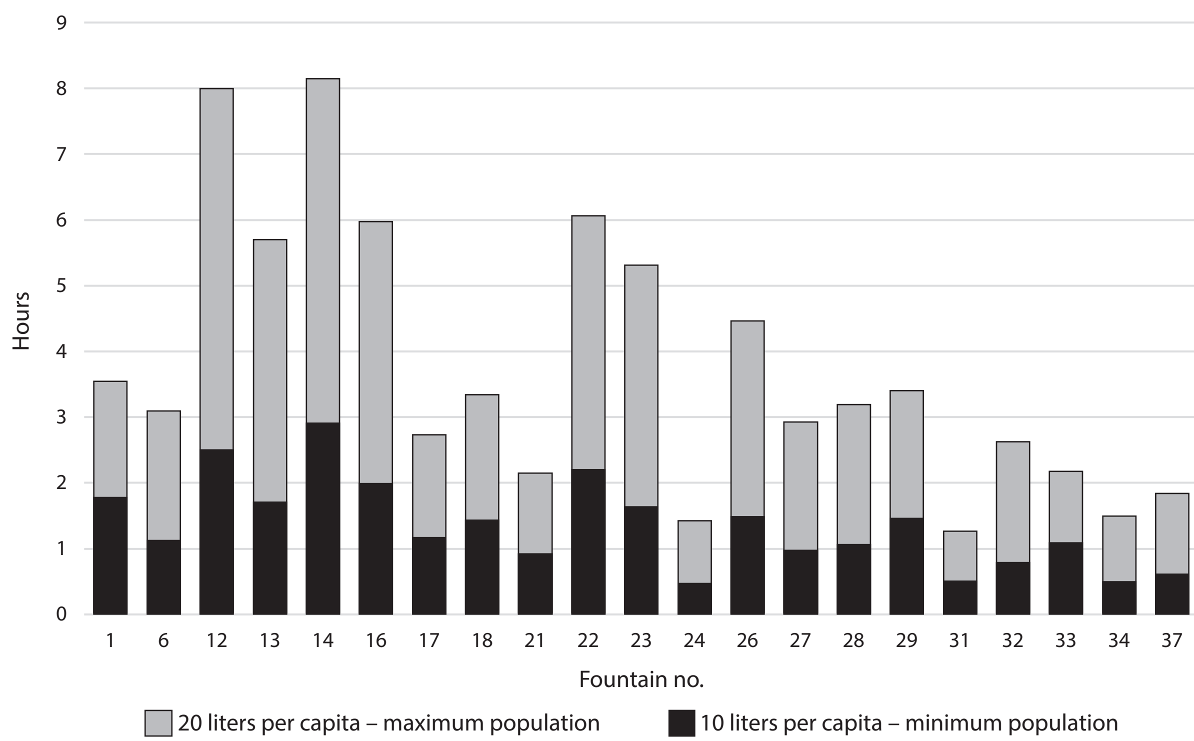


FIG. 13. Hours to fulfill district population water requirements at 0.43 liters per second flow rate (incomplete districts are excluded).

daily, and many others needed 2 to 4 hours, even at 10 liters per capita. If water collection was clustered early in the morning as suggested by comparative evidence, the basins would have been emptied below useful volumes rather quickly and users would have needed to collect water directly from the spigots, increasing wait times considerably. This accords with use-wear patterns on several fountains that show heaviest use closest to the taps, rather than evenly spread around the basin's accessible sides (see fig. 4).[173] Using fountain 12 as an example, a mere two draws with a 20-liter vessel per minute or three draws per minute with a 10-liter vessel were enough to lower the reserve faster than it could be refilled. A steady pace of four draws per minute with the larger vessel would leave the basin only half full in just over 7 minutes. It would require just under half an hour with a 10-liter vessel at the same pace to lower the reserve by half, but this represents a tiny fraction of the hundreds of draws per day required to fulfill the district population needs (online appx. tables 2–4). Moreover, the three fountains lacking a basin (11, 30, and 38) could only accommodate one person at a time. Of course, even slower inflow rates would have exacerbated not just supply shortages and queuing at peak times but also basin refresh rates at off-peak hours, impacting water quality and hygiene.[174]

The daily number of visits to each fountain is estimated by tallying the corresponding units' number of rounds trips at various vessel capacities (online appx. table 5). By aggregating these trips along routes, street traffic is quantified, showing not only the paths water fetchers likely took but also the cumulative volume of pedestrians along specific stretches (fig. 14).[175] The frequency of walker traffic on routes leading to fountains was substantial, but as with all these figures, household population, the daily water requirement, and the collecting vessel size were important factors. Using a 5-liter vessel, many fountains would have seen thousands of visits per day, but this would be far too inefficient for larger households. A large 20-liter vessel, on the other hand, would still require hundreds of visits to the busiest fountains per day, but only a few dozen to the least utilized. Intermediate ranges, using a 10-liter vessel, would still have generated several hundred daily trips to most fountains. Pathways in proximity to fountains were obviously busier than those farther away, but specific blocks were especially frequented. The Via Consolare, notably near the intersections with fountains 12 and 13, would have been extremely congested, as was the southern stretch of the Via di Mercurio north of Vicolo di Mercurio leading to fountain 14. That the Via Consolare saw some of the heaviest fountain activity is not astonishing, but the Via di Mercurio, dead-ending at the fortification, is a bit more unexpected. Also surprising is the considerable traffic generated on some secondary roads that do not score highly using other proxy measures of street activity, such as occurrence of doorways, total pathways, or depth from city gates.[176] One of these, Vicolo di Tesmo north of fountain 39, ranks highest in message frequency (such as painted election notices), however, surely reflecting this busyness. These data reify the impression gleaned from textual sources that fountains were neighborhood activity hubs and compel us to reconsider the role they played in local networks. For instance, the impacts of fountain activity on commercial spaces deserve further analysis beyond Ling's brief exploration of fountain 4 and the adjacent shop in I.10.1.[177] The fact that the shop's exterior door was subsequently walled off might indicate that the potential retail benefits of proximity did not materialize, or were in fact a hindrance, despite the hundreds of times a day the fountain was utilized.[178]

*Household Time and Energy Collecting Water*

Beyond neighborhood-level statistics, it is also useful to examine the variation in household time and energy devoted to water collection across the city. Most city residents had good water accessibility, but extreme inequality persisted for those at the system's margins. The degree of unequal access depends upon the modeled population, water requirements, and vessel size (see online figs. 2, 4). To illustrate these differences, three scenarios are explored here. The first, representing the maximum, assumes 20 liters per capita collected in small, 5-liter vessels at the maximum population estimate. The second, at the spectrum's lowest

[173] Jansen 2002, 46; Schmölder-Veit 2009, 129.

[174] Richard 2016, 277–81; Monteleone et al. 2021.

[175] An interactive map presenting the quantitative results of this study is available at https://mnotarian.github.io/Pompeii_Fountain_Map/.

[176] Laurence 2007, 73–84; Kaiser 2011, 77–89; Poehler 2017a, 180–97.

[177] Ling 2005.

[178] Ling 1997, 25–37.


FIG. 14. Aggregate pedestrian fountain traffic per day (maximum scenario).

end, uses 10 liters per capita collected in large, 20-liter vessels at the minimum population estimate. The discrepancy between these extremes is rather large, so a middling range is also used, to illustrate a feasible intermediate: 20 liters per capita, 10-liter vessels, at both the maximum and minimum population estimates.

In terms of distance, only slightly more than half (62%) of Pompeii's residents lived within 50 m of a public fountain, and 88% lived within 80 m (fig. 15). The 146 units in the remaining 12%, however, had widely varying access to water. Twelve units were more than 150 m away. The farthest unit was an upper-floor apartment near the fortification on Vicolo di Modesto (VI.5.1) that was 212 m away from any fountain. Since it is unlikely these residents had access to a ground-floor cistern, the public fountains would have been their only recourse. Overall, however, the round-trip times, using MP velocity, are rather low (online fig. 5). More than three-quarters of residents could reach a fountain in less than 2 minutes round trip, 98% were within 4 minutes of water, and the longest trip was just over 7 minutes.

Factoring in multiple trips according to population, water requirements, and vessel sizes drastically changes this initial impression. At the upper limit the average daily time spent fetching water was 44 minutes or 165

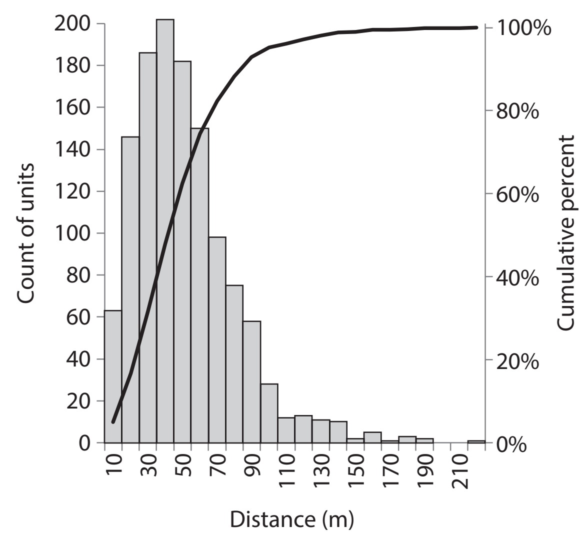


FIG. 15. Distribution of round-trip distance to closest fountain.

calories burned (fig. 16; online fig. 6). Only slightly more than half (56%) of Pompeii's units could collect their daily required water in half an hour (requiring 125 calories) or less, rising to 78% under an hour (225 calories). The remaining 275 units required multiple hours, mainly in the range of 2 to 4 (400 to 900 calories), but extreme outliers needed a maximum of 9 hours or almost 2,000 calories of combined labor.

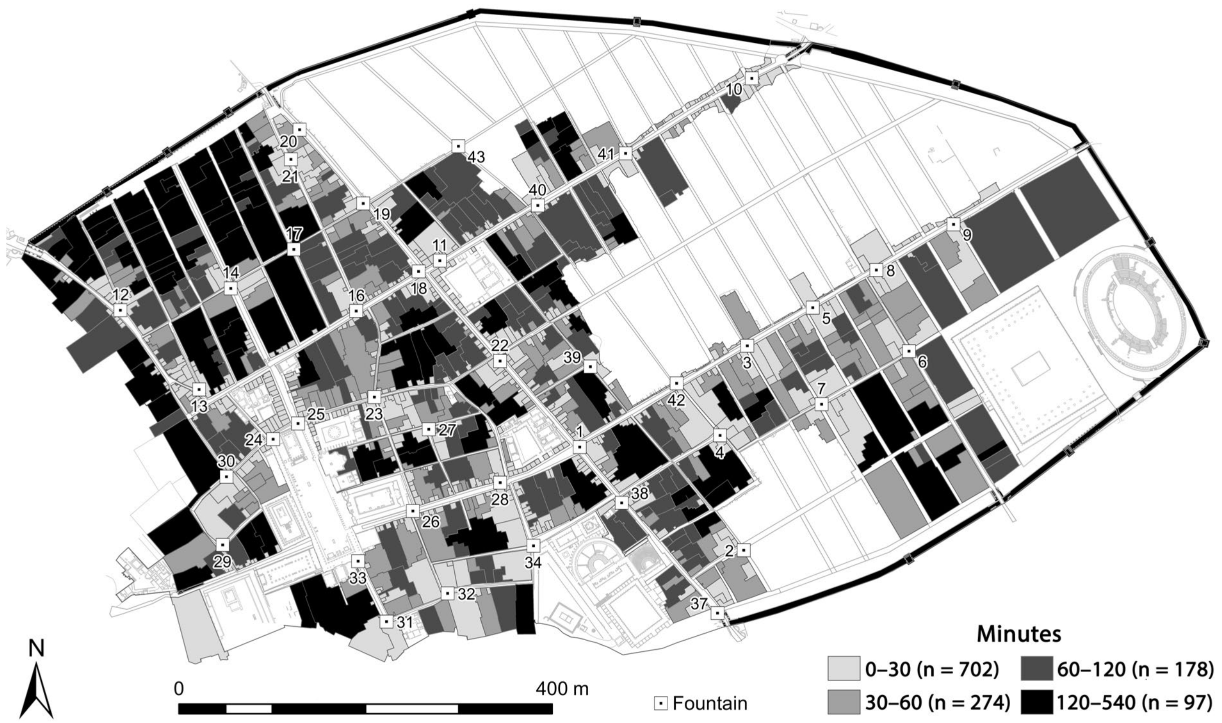


FIG. 16. Daily time fetching water at the maximum scenario (20 liters per capita, 5-liter vessel, maximum population estimate, MP speed; n = number of units).

On the spectrum's opposite end, with an average time under 4 minutes or 17 calories per unit, the situation would have been far more manageable (fig. 17; online fig. 7). Almost 92% of the city could have obtained 10 liters of water per capita in 10 minutes (45 calories) or less, and no unit required more than 46 minutes (200 calories). These bounds present an image of two completely different cities—one in which water hauling consumed inordinate time and energy, with a minority struggling to meet basic needs, and another in which water was easily accessible by almost everyone. This amounts to a difference of over 38 days or 200,000 calories of collective labor per day at the maximum scenario compared to only 3 days or 21,000 calories at the minimum. The minimum model, however, barely meets survival level needs for water. Alternate sources such as cisterns and private fountains would have been necessary, and deficiencies therein would have increased strain on the public system. The maximum model, on the other hand, likely exaggerates costs because a 5-liter vessel was untenable for larger or more distant households. Users would have chosen different-sized vessels depending on age, gender, distance to a fountain, and personal preference, so no model using a singular capacity represents a truly accurate quantification.

Therefore, the two intermediate models certainly represent a range closer to reality with a moderate 10-liter vessel and a sufficient 20 liters per capita (online figs. 8–11). At the maximum population estimate, 78% of Pompeii's units could obtain water in half an hour (125 calories) or less, rising to 92% at an hour (225 calories). However, as with the maximum scenario above, there is great discrepancy in the final 97 units, rising to three hours (almost 700 calories) with extreme outliers over 4 hours (1,000 calories). At the minimum population, 88% could obtain water in half an hour (125 calories) and a high 97% were supplied in one hour (225 calories) or less. A mere 39 units required longer than an hour, with the highest outlier just under 3 hours (700 calories). (In present-day developing countries, 3- to 4-hour ranges correspond with severe scenarios, which typically result from overcrowding and long queues in urban environments or longer distance trips during dry weather in rural areas.) The spatial network model does not factor waiting or crowding into time estimates, so additional time was likely necessary at heavily trafficked fountains.


FIG. 17. Daily time fetching water at the minimum scenario (10 liters per capita, 20-liter vessel, minimum population estimate, MP speed; n = number of units).

Nonetheless, the intermediate range represents daily collective labor of 288 to 460 hours, or 67,000 to 108,000 calories, a much narrower spread than the two extremes.

Spatially, high- and low-cost units are distributed haphazardly, as household population and distance from a fountain are the key determinant variables. High costs resulted either from a large household population or a long distance to a fountain, with varying effects dependent on each variable's exact share, along with other local factors such as the terrain slope (online fig. 12). There is one key exception, however, in the city's northwest corner, especially near the fortification in Regio VI where high costs cluster. Of the 100 units with the highest costs in the maximum scenario, 47 are located here. Insulae 1, 2, 5, 7, and 11 average 118 to 10 minutes at both extremes and 59 to 37 minutes in the intermediate range. The region had both a dense population owing to a higher share (58%) of larger (third and fourth quartile) units as well as longer than average distances to a fountain, making it the most problematic part of the city for water accessibility. This remoteness may also have been influenced by the sector's high elevation, which may have restricted fountain placement.[179] As previously discussed, fountains 12 and 14 were also the most trafficked, increasing the likelihood that they suffered from insufficient basin reserves and extended queuing. Long distances to a fountain are also found near Porta Nocera, particularly the insulae abutting the fortification in regions I and II. Although the large unexcavated sector of Regio I renders these figures tentative, it seems unlikely fountain 6 or 7 experienced similar overcrowding, given the much sparser population in this zone.

## CONCLUSION

Spatial network modeling offers a valuable methodology to test the parameters of public water collection across Pompeii. While it largely reinforces earlier impressions that the city's hydraulic system provided sufficient water levels for household use, it nonetheless makes clear there was disproportionate inequality at peripheries. Fountains across the city were utilized at different rates, and a statistically significant positive correlation between basin size and units served

[179] Keenan-Jones 2015, 198–99.

indicates some degree of civic planning. Yet the municipal authority's attempts to regulate these discrepancies through varying basin sizes were haphazard, at best, or hampered by topographical limitations and seismic events. More abundant data on cistern capacities and water volume delivered via the aqueduct given seismic and environmental constraints could help clarify the contribution of public fountains and their potential deficiencies at points of stress. In addition, hypotheses about the system's evolution could be tested by comparing various iterations of the fountain network with and without certain nonstandard fountain types that might have been added to fill systemic gaps or relieve overuse at crowded locations. Likewise, more data are needed to understand how service disruptions in the city's final decades affected public fountain distribution, especially given textual evidence of social unrest tied to water insecurity.

Nonetheless, these models rely on a strictly rational water collection strategy that likely conceals the true complexity of human behavior.[180] Since enslaved individuals undertook much of this labor, more distant fountains were perhaps frequented in acts of overt resistance and avoidance.[181] Conversely, given the concern expressed in legal sources (e.g., *Dig*. 21.1.18) over slave idleness, their freedom of movement was potentially restricted to the closest sources. Users may also have avoided overcrowded fountains or traveled farther to take advantage of nearby commercial premises or benches. An agent-based model may shed light on the systemic effects of these different behaviors by incorporating carriers of different ages, genders, and statuses. Social network analysis could help further elucidate the topological structure of subelite communities that are largely invisible in the material or textual record.

Water retrieval's dynamic nature also complicates our understanding of what constituted the natural neighborhoods formed by fountain users. Even without factoring in the vagaries of human behavior, multiple doors and liminal units presented broadly equivalent choices to water haulers. Topography also influenced their boundaries, shifting routes uphill or downhill depending on the load carried. The composition of fountain neighborhoods was far more fluid than static maps typically represent. That is not to say, however, each fountain did not have a core group of regular fetchers around which social relations were structured. While attempts to define a local identity based on the fountain's decorative reliefs defy straightforward symbolism, spatial networking modeling moves analysis beyond iconography or simple distance toward quantifiable measures of accessibility and cohesion. Among the subaltern populations who relied on publicly distributed water, some labored for hours a day to meet minimum living standards and likely suffered the socioeconomic and health consequences of water carriage and supply inadequacy. The majority, however, benefited from an imperial benefaction that rendered better water accessibility than even some contemporary disadvantaged communities. This is an important first step toward repopulating Pompeii's streets with indispensable but often forgotten laborers beyond elite authors' biased anecdotes.

Matthew Notarian
Department of History and Classical Studies
Hiram College
Hiram, Ohio
notarianmf@hiram.edu

[180] See Ellis' (2018, 93–94) critiques of data-driven spatial studies of Roman cities and their tendency to minimize the "countless complexities of urban life." Similar caveats in Siefried and Gardner (2019, 408).

[181] Joshel and Petersen 2015, 99–117.

## Works Cited

Agusta-Boularot, S. 2008. "Le *lacus* de la rue Romaine: Un exemple de 'mobilier urbain' antique?" In *La rue dans l'antiquité: Définition, aménagement et devenir*, edited by P. Ballet, N. Dieudonné-Glad, and C. Saliou, 93–100. Rennes: Presses Universitaires de Renne.

Ainsworth, B.E., W.L. Haskell, S.D. Herrmann, N. Meckes, D.R. Bassett, C. Tudor-Locke, J.L. Greer, J. Vezina, M.C. Whitt-Glover, and A.S. Leon. 2011. "Compendium of Physical Activities: A Second Update of Codes and MET Values." *Medicine and Science in Sports and Exercise* 43: 1575–581.

Aldrete, G., and A. Aldrete. 2012. *The Long Shadow of Antiquity: What Have the Greeks and Romans Done for Us?* London: Bloomsbury.

Allison, P. 2006. *The Insula of the Menander at Pompeii*. Vol. 3, *The Finds: A Contextual Study*. Oxford: Clarendon.

Andersson, E. 1990. "Fountains and the Roman Dwelling: Casa del Torello in Pompeii." *JdI* 105:207–36.

———. 1994. "Urban Water Supply in Pompeii and the Private Water Consumption." In *Actos XIV Congreso Internacional de arqueología clásica, Tarragona, 5 al 11-9-1993*, edited by X. Dupre Raventos, 29–31. Tarragona: Comite Organitzador del XIV C.I.A.C. and Consejo Superior de Investigaciones Cientificas, Institut d'Estudis Catalans.

Appler, D., J. Bidmead, and M. Love. 2020. "Women, Water, and Walkways: Preliminary Findings from the Jezreel Expedition in Light of Biblical and Archaeo-Ethnographic Evidence." In *The Woman in the Pith Helmet: A Tribute to Archaeologist Norma Franklin*, edited by J. Ebeling and P. Guillaume, 3–18. Atlanta: Lockwood Press.

Ash, H.B., trans. 1941. *On Agriculture*, by Columella. Vol. 1. Loeb Classical Library 361. Cambridge, Mass.: Harvard University Press.

Benefiel, R. 2016. "The Culture of Writing Graffiti Within Domestic Spaces at Pompeii." In *Inscriptions in the Private Sphere in the Greco-Roman World,* edited by R. Benefiel and P. Keegan, 80–110. Leiden: Brill.

Benefiel, R., J. DiBiasie, and H. Sypniewski. 2016. "The Herculaneum Graffiti Project: Initial Field Season 2014." *Fasti Online Documents & Research*. www.fastionline.org/docs/FOLDER-it-2016-361.pdf.

Berg, R. 2018. "Furnishing the Courtesan's House: Material Culture and Elite Prostitution in Pompeii." In *The Roman Courtesan: Archaeological Reflections of a Literary Topos*, edited by R. Berg and R. Neudecker, 193–220. *ActaInstRomFin* 46. Rome: Institutum Romanum Finlandiae.

———. 2019. "Dress, Identity, Cultural Memory: Copa and Ancilla Cauponae in Context." In *Gender, Memory, and Identity in the Roman World*, edited by J. Rantala, 203–38. Amsterdam: Amsterdam University Press.

Bruun, C. 1991. *The Water Supply of Ancient Rome: A Study of Roman Imperial Administration.* Helsinki: Finnish Society of Sciences and Letters.

———. 1997a. "Acquedotti e condizioni sociali di Roma imperial: Immagini e realtà." In *La Rome impériale: Démographie et logistique. Actes de la table ronde de Rome, 25 mars 1994*, 121–55. Rome: École Française de Rome.

———. 1997b. "Water for Roman Brothels: Cicero *Cael.* 3.34." *Phoenix* 51(3/4):364–73.

———. 2012. "Stallianus, A Plumber from Pompeii (and Other Remarks on Pompeian Lead Pipes)." *Phoenix* 66(1/2):145–57.

Bundrick, S. 2019. *Athens, Etruria, and the Many Lives of Greek Figured Pottery*. Madison: University of Wisconsin Press.

Butrica, J. 1999. "Using Water 'Unchastely': Cicero *Pro Caelio* 34 Again." *Phoenix* 53(1/2):136–39.

Choi, J.H., E.R. Galea, and W.H. Hong. 2014. "Individual Stair Ascent and Descent Walk Speeds Measured in a Korean High-Rise Building." *Fire Technology* 50:267–95. https://doi.org/10.1007/s10694-013-0371-4.

Consani, C. 2001. *Studi e ricerche di terminologia alimentaria.* Alessandria: Edizioni dell'Orso.

Crouch, D. 1993. *Water Management in Ancient Greek Cities.* Oxford: Oxford University Press.

Crow, J. 2012. "Water and Late Antique Constantinople." In *Two Romes: Rome and Constantinople in Late Antiquity,* edited by L. Grig and G. Kelly, 116–35. Oxford: Oxford University Press.

Davidson, C. 1982. *A Woman's Work is Never Done: A History of Housework in the British Isles 1650–1950.* London: Chatto and Windus.

de Haan, N. 2010. *Römische Privatbäder: Entwicklung, Verbreitung, Struktur und Sozialer Status.* Frankfurt: Peter Lang.

de Kleijn, G. 2001. *The Water Supply of Ancient Rome: City Area, Water, and Population.* Amsterdam: J.C. Gieben.

de Melo, W., trans. 2011. *Casina. The Casket Comedy. Curculio. Epidicus. The Two Menaechmuses*, by Plautus. Loeb Classical Library 61. Cambridge, Mass.: Harvard University Press.

Del Chicca, F. 1997. "Terminologia delle fontane pubbliche a Roma: *Lacus, salientes, munera*." *Rivista di cultura classica e mediovale* 39(2):231–53.

Descoeudres, J.P., and F. Sear. 1987. "The Australian Expedition to Pompeii." *RStPomp* 1:11–36.

Dessales, H. 2011. "L'eau en partage: Les raccordements hydrauliques dans les maisons et structures artisanales (Herculanum, Pompéi)." In *La ville au quotidien: Regards croisés sur l'habitat et l'artisanat antiques. Afrique du nord, Gaule et Italie: Actes du colloque international Maison méditerranéenne des sciences de l'homme, Aix-en-Provence, 23 et 24 novembre 2007,* edited by S. Fontaine, S. Satre, and A. Tekki, 137–51. Aix-en-Provence: Publications de l'université de Provence.

———. 2013. *Le partage de l'eau: Fontaines et distribution hydraulique dans l'habitat urbain de l'Italie romaine*. Rome: École française de Rome.

Dietrich, M., O. Loretz, and J. Sanmartín, eds. 1995. *The Cuneiform Alphabetic Texts from Ugarit, Ras Ibn Hani, and Other Places (KTU).* 2nd ed. Münster: Ugarit-Verlag.

Edlund-Berry, I. 2006. "Hot, Cold, or Smelly: The Power of Sacred Water in Roman Religion, 400–100 BCE." In *Religion in Republican Italy,* edited by C.E. Schultz and P.B. Harvey, 162–80. Cambridge: Cambridge University Press.

Edmondson, J. 2011. "Slavery and the Roman Family." In *The Cambridge World History of Slavery*. Vol. 1, *The Ancient Mediterranean World,* edited by K. Bradley and P. Cartledge, 337–61. Cambridge: Cambridge University Press.

Ellis, S. 2018. *The Roman Retail Revolution: The Socio-Economic World of the Taberna.* Oxford: Oxford University Press.

Ellis, S., and G. Devore. 2010. "The Fifth Season of Excavations at VIII.7.1–15 and the Porta Stabia at Pompeii: Preliminary Report." *Fasti Online Documents & Research*. www.fastionline.org/docs/FOLDER-it-2010-202.pdf.

Ellis, S., A. Emmerson, A. Pavlick, and K. Dicus. 2011. "The 2010 Field Season at I.1.1–10, Pompeii: Preliminary Report on the Excavations." *Fasti Online Documents & Research*. www.fastionline.org/docs/FOLDER-it-2011-220.pdf.

Emmerson, A.L.C. 2020. *Life and Death in the Roman Suburb*. Oxford: Oxford University Press.

Eschebach, H. 1979. "Die Gebrauchswasserversorgung des antiken Pompeji." *AntW* 10(2):3–24.

———. 1982. "Katalog der pompejanischen Laufbrunnen und ihre Reliefs." *AntW* 13(2):21–26.

Eschebach, H., and T. Schäfer. 1983. "Die öffentlichen Laufbrunnen Pompejis: Katalog und Beschreibung." *Pompeii, Herculaneum, Stabiae: Bollettino dell'Associazione Internazionale Amici di Pompei* 1:11–40.

Eschebach, L., H. Eschebach, and J. Müller-Trollius. 1993. *Gebäudeverzeichnis und Stadtplan der antiken Stadt Pompeji*. Cologne: Böhlau.

Felice, C. 1990. *Il Disagio di Vivere: Il cibo, la casa, le malattie in Abruzzo e Molise dall'Unità al secondo dopoguerra*. Milan: Franco Angeli.

Fiorelli, G., ed. 1860–64. *Pompeianarum antiquitatum historia.* 3 vols. Naples: n.p.

Flohr, M. 2017. "Quantifying Pompeii: Population, Inequality, and the Urban Economy." In *The Economy of Pompeii*, edited by M. Flohr and A. Wilson, 53–84. Oxford: Oxford University Press.

———. 2018. *Database of Pompeian Houses.* www.mikoflohr.org/pompeii/.

Frazer, J.G., trans. 1931. *Fasti*, by Ovid. Loeb Classical Library 253. Cambridge, Mass.: Harvard University Press.

Geere, J-A., and M. Cortobius. 2017. "Who Carries the Weight of Water? Fetching Water in Rural and Urban Areas and the Implications for Water Security." *Water Alternatives* 10:513–40.

Geere, J.-A.L., M. Cortobius, J.H. Geere, C.C. Hammer, and P.R. Hunter. 2018. "Is Water Carriage Associated with the Water Carrier's Health? A Systematic Review of Quantitative and Qualitative Evidence." *BMJ Global Health* 3:1–24. https://doi.org/10.1136/bmjgh-2018-000764.

Gersht, R., and S. Mucznik. 1988. "Mars and Rhea Silvia." *Gerión* 6:115–33.

Goold, G.P., trans. 1990. *Elegies*, by Propertius. Loeb Classical Library 18. Cambridge, Mass.: Harvard University Press.

Graham, J., M. Hirai, and S.-S. Kim. 2016. "An Analysis of Water Collection Labor Among Women and Children in 24 Sub-Saharan African Countries." *PLOS ONE* 11:1–14. https://doi.org/10.1371/journal.pone.0155981.

Gulick, C.B., trans. 1927. *The Deipnosophists*, by Athenaeus. Vol. 1. Loeb Classical Library 204. Cambridge, Mass.: Harvard University Press.

Hartnett, J. 2017. *The Roman Street: Urban Life and Society in Pompeii, Herculaneum, and Rome.* New York: Cambridge University Press.

Hellmann, M.-C. 1994. "L'eau des citernes et la salubrité: Textes et archéologie." In *L'eau, la santé et la maladie dans le monde grec: Actes du colloque, 25–27 novembre 1992,* edited by R. Ginouvès, A.-M. Guimier-Sorbets, J. Jouanna, and L. Villard, 273–82. Athens: École Française d'Athènes.

Herzog, I. 2020. "Spatial Analysis Based on Cost Functions." In *Archaeological Spatial Analysis: A Methodological Guide*, edited by M. Gillings, P. Hacıgüzeller, and G. Lock, 333–58. London: Routledge.

Higgins, J.D. 2019. "A 4D Spatio-Temporal Approach to Modelling Land Value Uplift from Rapid Transit in High Density and Topographically-Rich Cities." *Landscape and Urban Planning* 185:68–82.

Hodge, A.T. 2002. *Roman Aqueducts and Water Supply.* 2nd ed. London: Duckworth.

Jansen, G. 2001. "Water Pipe Systems in the Houses of Pompeii." In *Water Use and Hydraulics in the Roman City,* edited by A. Koloski-Ostrow, 27–40. Boston: Archaeological Institute of America.

———. 2002. *Water in de Romeinse Stad: Pompeeji-Herculaneum-Ostia.* Leuven: Peeters.

Jones, R., and D. Robinson. 2005. "Water, Wealth, and Social Status at Pompeii: The House of the Vestals in the First Century A.D." *AJA* 109(4):695–710.

Jones, W.H.S., trans. 1963. *Natural History*, by Pliny. Vol. 8. Loeb Classical Library 418. Cambridge, Mass.: Harvard University Press.

Joshel, S., and L. Petersen. 2015. *The Material Life of Roman Slaves.* New York: Cambridge University Press.

Kaiser, A. 2011. *Roman Urban Street Networks.* New York: Routledge.

Keegan, P. 2016. "Graffiti as *Monumenta* and *Verba*: Marking Territories, Creating Discourses in Roman Pompeii." In *Inscriptions in the Private Sphere in the Greco-Roman World,* edited by R. Benefiel and P. Keegan, 248–64. Leiden: Brill.

Keenan-Jones, D.C. 2015. "Somma-Vesuvian Ground Movements and the Water Supply of Pompeii and the Bay of Naples." *AJA* 119(2):191–215.

———. 2016. "Fountains, Lead Pipes and Water Systems in Pompeii, Rome and the Roman West." *JRA* 29:778–85.

Keenan-Jones, D.C., J.C. Hellstrom, and R.N. Drysdale. 2011. "Lead Contamination in the Drinking Water of Pompeii." In *Pompeii: Art, Industry and Infrastructure*, edited by E. Poehler, M. Flohr, and K. Cole, 131–48. Oxford: Oxbow.

Klingborg, P., and M. Finné. 2018. "Modelling the Freshwater Supply of Cisterns in Ancient Greece." *Water History* 10:113–31. https://doi.org/10.1007/s12685-017-0209-y.

Kockel, V. 2005. "Altes und Neues vom Forum und vom Gebäude der Eumachia in Pompeji." In *Lebenswelten: Bilder und Räume in der römischen Stadt der Kaiserzeit*, edited by R. Neudecker and P. Zanker, 51–72. Weisbaden: Ludwig Reichert.

Lamare, N. 2020. "Fountains and the Ancient City." In *The Power of Urban Water,* edited by N. Chiarenza, A. Haug, and U. Müller, 31–50. Berlin: de Gruyter.

Larsen, J.D. 1982. "The Water-Towers in Pompeii." *Analecta Romana* 11:41–67.

Laurence, R. 2007. *Roman Pompeii: Space and Society*. 2nd ed. London: Routledge.

Laurence, R., and D. Newsome. 2011. *Rome, Ostia, Pompeii: Movement and Space*. Oxford: Oxford University Press.

Lavan, L. 2020. *Public Space in the Late Antique City*. Vol. 1, *Streets, Processions, Fora, Agorai, Macella, Shops.* Leiden: Brill.

Leander Touati, A.-M. 2010. "Water, Well-Being and Social Complexity in Insula V 1: A Pompeian City Block Revisited." *OpAthRom* 3:105–61.

Levin-Richardson, S. 2019. *The Brothel of Pompeii: Sex, Class, and Gender at the Margins of Roman Society.* Cambridge: Cambridge University Press.

Ling, R. 1997. *The Insula of the Menander at Pompeii.* Vol. 1, *The Structures*. Oxford: Clarendon.

———. 2005. "Street Fountains and House Fronts at Pompeii." In *Omni pede stare: Saggi architettonici e circumvesuviani in memoriam Jos de Waele,* edited by S.T.A.M. Mols and E. Moormann, 271–76. Naples: Electa Napoli.

Lund, J. 2011. "Iconographic Evidence for the Handling and Use of Transport Amphorae in the Roman Period." In *Pottery in the Archaeological Record: Greece and Beyond. Acts of the International Colloquium Held at the Danish and Canadian Institutes in Athens, June 20–22, 2008*, edited by M. Lawall and J. Lund, 52–60. Aarhus: Aarhus University Press.

Magnusson, R. 2001. *Water Technology in the Middle Ages: Cities, Monasteries, and Waterworks after the Roman Empire.* Baltimore: Johns Hopkins University Press.

Maiuri, A. 1931. "Pozzi e Condutture d'acqua nell'antica città: Scoperta di un antico pozzo presso 'Porta Vesuvio.'" *NSc*:546–76.

———. 1973. *Alla Ricerca di Pompei Preromana*. Naples: Società Editrice Napoletana.

Márquez-Pérez, J., I. Vallejo-Villalta, and J.I. Álvarez-Francoso. 2017. "Estimated Travel Time for Walking Trails in Natural Areas." *Geografisk Tidsskrift-Danish Journal of Geography* 117:53–62. https://doi.org/10.1080/00167223.2017.1316212.

Mau, A. 1895. "Segni di scarpellino di Pompei." *RM* 10: 47–51.

Mayerson, P. 1986. "Choricius of Gaza on the Watersupply System of Caesarea." *IEJ* 36(3/4):269–72.

Mello, M. 1995. "Le fontane di P Claudius e C. Sextilius a Paestum: Nuove iscrizioni." In *Tra Lazio e Campania: Ricerche di storia e di topografia antica*, 103–11. Naples: Arte tipolografica.

Molina Vidal, J., and D. Mateo Corredor. 2018. "The Roman Amphorae Average Capacity (AC)." *OJA* 37:299–311.

Monteleone, M.C., M. Crapper, and D. Motta. 2021. "The Supply of the Public Lacus of Pompeii, Estimated from the Discharge of Their Overflow Channels." *Water History* 13:189–216. https://doi.org/10.1007/s12685-021-00281-9.

Muslin, J. 2019. "Between Farm and Table: The Dynamics of Amphora Packaging, Design, and Reuse on the Bay of Naples." Ph.D. diss., University of Texas at Austin.

———. Forthcoming. *Oplontis B: The Amphorae and Packaging Equipment from the Soprintendenza Archeologica di Pompeii Excavations, 1973–1991*. Ann Arbor: University of Michigan Press and American Council of Learned Societies.

Mustaţă, S. 2011. "Remarks on the Use and Misuse of Latin Terms in the Study of Roman Bronze Vessels." In *Studies in Archaeology and History: An Anniversary Volume to Professor Nicolae Gudea on His 70th Birthday*, edited by C. Cosma, 233–39. Cluj-Napoca: Editura Mega.

Nappo, S.C. 2002. "L'impianto idrico a Pompei: Documentazione e nuovi dati." In *Atti del Convegno internazionale di studi su metodologie per lo studio della scienza idraulica antica (Ravenna, 13–15 maggio 1999)*, 91–108. La Spezia: Agorà Edizioni.

Nishida, Y. 1991. "Measuring Structures in Pompeii." *Opuscula Pompeiana* 1:91–102.

Norman, A.F. 2000. *Antioch as a Centre of Hellenic Culture as Observed by Libanius*. Liverpool: Liverpool University Press.

Norman, C.R. 2009. "Warriors and Weavers: Sex and Gender in Daunian Stele." In *Gender Identities in Italy in the First Millennium BC*, edited by E. Herring and K. Lomas, 37–54. Oxford: British Archaeological Reports.

Ohlig, C. 2001. *De Aquis Pompeiorum: Das Castellum Aquae in Pompeji. Herkunft, Zuleitung und Verteilung des Wassers*. Nijmegen: C. Ohlig.

Oleson, J.P. 1984. *Greek and Roman Mechanical Water Lifting Devices: The History of a Technology.* Dordrecht: D. Reidel.

Olsson, R. 2015. "The Water-Supply System in Roman Pompeii." Ph.D. diss., Lund University.

Pandolf, K.B., B. Givoni, and R.F. Goldman. 1977. "Predicting Energy Expenditure with Loads While Standing or Walking Very Slowly." *Journal of Applied Physiology* 43:577–81.

Panella, C., and M. Fano. 1977. "Le anfore con anse bifide conservate a Pompei: Contribute ad una loro classificazione." In *Méthodes classiques et méthodes formelles dans l'étude des amphores: Actes du Colloque de Rome, 27–29 mai 1974*, 133–77. Rome: École Française de Rome.

Parker, H. 1997. "The Teratogenic Grid." In *Roman Sexualities,* edited by J. Hallett and M. Skinner, 47–65. Princeton: Princeton University Press.

Peña, J.T. 2007. *Roman Pottery in the Archaeological Record.* Cambridge: Cambridge University Press.

Peña, J.T., and M. McCallum. 2009a. "The Production and Distribution of Pottery at Pompeii: A Review of the Evidence. Part 1: Production." *AJA* 113(1):57–79.

———. 2009b. "The Production and Distribution of Pottery at Pompeii: A Review of the Evidence. Part 2: The Material Basis for Production and Distribution." *AJA* 113(2): 165–201.

Petersen, L.H. 1997. "Divided Consciousness and Female Companionship: Reconstructing Female Subjectivity on Greek Vases." *Arethusa* 30:35–74.

Pirson, F. 1999. *Mietwohnungen in Pompeji und Herkulaneum: Untersuchungen zur Architektur, zum Wohnen und zur Sozial- und Wirtschaftsgeschichte der Vesuvstädtei.* Munich: Pfeil.

Poehler, E. 2011. "Practical Matters: Infrastructure and the Planning for the Post-Earthquake Forum at Pompeii." In *Pompeii: Art, Industry and Infrastructure*, edited by E. Poehler, M. Flohr, and K. Cole, 149–63. Oxford: Oxbow.

———. 2017a. "Measuring the Movement Economy: A Network Analysis of Pompeii." In *The Economy of Pompeii*, edited by M. Flohr and A. Wilson, 163–207. Oxford: Oxford University Press.

———. 2017b. *The Traffic Systems of Pompeii.* New York: Oxford University Press.

Poehler, E., and B. Crowther. 2018. "Paving Pompeii: The Archaeology of Stone-Paved Streets." *AJA* 122(4):579–609.

Poehler, E, and S. Ellis. 2014. "The 2013 Season of the Pompeii Quadriporticus Project: Final Fieldwork and Preliminary Results." *Fasti Online Documents & Research* 321:1–10. www.fastionline.org/docs/FOLDER-it-2014-322.pdf.

Ray, I. 2007. "Women, Water, and Development." *Annual Review of Environment and Resources* 32:421–49. https://doi.org/10.1146/annurev.energy.32.041806.143704.

Richard, J. 2012. *Water for the City, Fountains for the People: Monumental Fountains in the Roman East.* Turnhout: Brepols.

———. 2016. "Stagnant Beauties? Some Reflections on the Speed of the Water Flow in Roman *Nymphaea*." In *De aquaeductu atque aqua urbium Lyciae Pamphyliae Pisidiae: The Legacy of Sextus Julius Frontinus*, edited by G. Wiplinger, 275–81. Leuven: Peeters.

Richardson, L. 1988. *Pompeii: An Architectural History*. Baltimore: Johns Hopkins University Press.

Robinson, D. 1997. "The Social Texture of Pompeii." In *Sequence and Space in Pompeii*, edited by R. Jones and S. Bon, 135–44. Oxford: Oxbow.

Rogers, D. 2018. *Water Culture in Roman Society.* Leiden: Brill.

Rolf, N. 1884. *Pompeii, Past and Present*. London: William Clowes and Sons.

Santee, W.R., L.A. Blanchard, K.L. Speckman, J.A. Gonzalez, and R.F. Wallace. 2003. *Load Carriage Model Development and Testing with Field Data.* Technical Note No. ADA#415788. Natick, Mass.: Army Research Institute of Environmental Medicine.

Schmeling, G.L., ed. and trans. 2020. *Satyricon*, by Petronius. *Apocolocyntosis*, by Seneca. Seneca 11, Loeb Classical Library 15. Cambridge, Mass.: Harvard University Press.

Schmölder-Veit, A. 2009. *Brunnen in den Städten des westlichen Römischen Reiches*. Palilia 19. Wiesbaden: Ludwig Reichert.

Sharma, R., and R. Singh. 2012. "Determination of Safe Carrying Load Limit for Women Carrying Water." *Journal of Ergonomics* 2:103. https://doi.org/10.4172/2165-7556.1000103.

Siefried, R., and C. Gardner. 2019. "Reconstructing Historical Journeys with Least-Cost Analysis: Colonel William Leake in the Mani Peninsula, Greece." *JAS Reports* 24:391–411.

Sorenson, S., C. Morssink, and P. Campos. 2011. "Safe Access to Safe Water in Low Income Countries: Water Fetching in Current Times." *Social Science and Medicine* 72:1522–526.

Stambaugh, J. 1988. *The Ancient Roman City.* Baltimore: Johns Hopkins University Press.

Staub, T. 2013. "The Casa del Torello di Bronzo (V 1,7) in Pompeii: Investigating a Residential House and Its Complex Water System." Ph.D. diss., Stockholm University.

Stroka, V.M. 1984. *Casa del Principe di Napoli (VI 15, 7–8)*. Häuser in Pompeji 1. Tübingen: Wasmuth.

Thomas, R., and A. Wilson. 1994. "Water Supply for Roman Farms in Latium and South Etruria." *PBSR* 62:139–96.

Tobler, W. 1993. *Three Presentations on Geographical Analysis and Modeling: Non-Isotropic Modeling Speculations on the Geometry of Geography Global Spatial Analysis*. National Center for Geographic Information and Analysis 93-1. Santa Barbara: University of California Santa Barbara.

UN Office of the High Commissioner for Human Rights. 2010. *Fact Sheet No.25: The Right to Water.* www.ohchr.org/Documents/Publications/FactSheet35en.pdf.

van der Poel, H.B. 1984. *Corpus Topographicum Pompeianum. Pars III. The RICA Maps of Pompeii*. Rome: University of Texas at Austin.

van Nes, A. 2014. "Indicating Street Vitality in Excavated Towns: Spatial Configurative Analyses Applied to Pompeii." In *Spatial Analysis and Social Spaces: Interdisciplinary Approaches to the Interpretation of Prehistoric and Historic Built Environments*, edited by E. Paliou, U. Lieberwirth, and S. Polla, 277–96. Berlin: De Gruyter.

van Tilburg, C. 2013. "Greek and Roman Ideas about Healthy Drinking-Water in Theory and Practice." *Eä – Revista de Humanidades Médicas & Estudios Sociales de la Ciencia y la Tecnología* 5.1. www.ea-journal.com/images/stories/Art0501/Articulo_-_Van_Tillburg_-_Drinking_water.pdf.

Wallace-Hadrill, A. 1994. *Houses and Society in Pompeii and Herculaneum.* Princeton: Princeton University Press.

Watson. A., ed. and trans. 1985. *The Digest of Justinian*. Vol. 4. Philadelphia: University of Pennsylvania Press.

Wernke, S. 2012. "Spatial Network Analysis of a Terminal Prehispanic and Early Colonial Settlement in Highland Peru." *JAS* 39:1111–122.

Wernke, S., L. Kohut, and A. Traslaviña. 2017. "A GIS of Affordances: Movement and Visibility at a Planned Colonial Town in Highland Peru." *JAS* 84:22–39.

White, K.D. 1975. *Farm Equipment of the Roman World.* Cambridge: Cambridge University Press.

Wilson, A.I. 2006. "Water for the Pompeians." Review of *De Aquis Pompeiorum: Das Castellum Aquae in Pompeji. Herkunft, Zuleitung und Verteilung des Wassers*, by C. Ohlig. *JRA* 19:501–8.

World Health Organization. 2017. *Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First Addendum.* Geneva: World Health Organization.

Zanella, S. 2021. "The Tabernae Outside Porta Ercolano in Pompeii and Their Context." In *Urban Space and Urban History in the Roman World*, edited by M. Flohr, 286–306. New York: Routledge.