The Lower Aqueduct of Jerusalem

<u>Location</u>: The west bank of the Hinnom Valley, above the Sultan's Pool and near the entrance to Mishkenot Sha'ananim. The aqueduct structure can be viewed both from the stepped path which runs below it and from the paved overlook above.

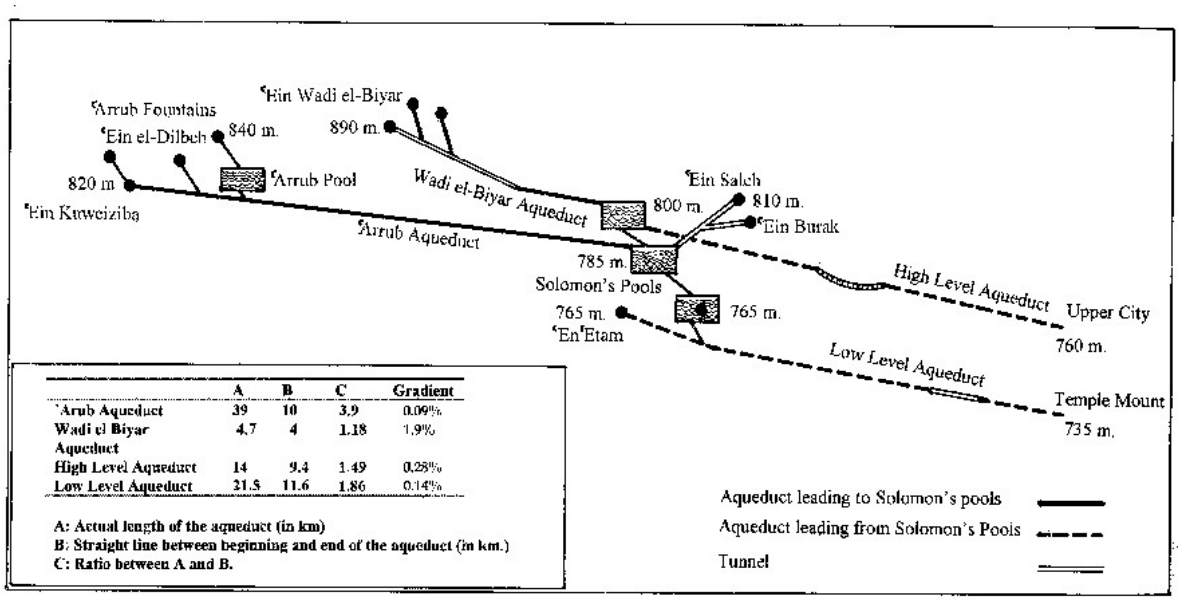
The aqueduct represents a true link between antiquity and modern times: From its original construction in the Hasmonean period, it continued to deliver water to Jerusalem (off and on, through various alterations) until the turn of the 20th Century! (Other parts of the system were actually supplying water to the Old City until 1967.)

The segment of several meters that has been restored and left exposed here is a small part of a system that stretches over 60 km from its furthest sources to its destination. It is vast and ingenious, representing the finest of ancient engineering, and is easily the longest and most complex aqueduct system in the Land of Israel, including even Caesarea.

What we see here is quite simple: The constructed water channel is elevated atop a buttressed stone wall, in order to maintain the required gradient; it is plastered inside to prevent leakage and capped with stone slabs **[PHOTO]** in order to minimize evaporation and contamination of the water. (What we actually see is the aqueduct as rebuilt and repaired in the late Ottoman period, but at its core it is Hasmonean.) It can only be properly understood in relation to the larger system of which it is one part.

<u>An overview of Jerusalem's aqueduct system</u>:

The system, which reached its height in the late Second Temple period, consists of several independent but interconnected elements which were built/re-built at different times. It was explored & mapped by the 19th century explorers Charles Wilson and Conrad Schick and again in recent times by Amihai Mazar and others. Think of the aqueduct system in terms of the **human circulatory system**: a **heart, veins, and arteries**.



	A	B	C	Gradient
ʿArub Aqueduct	39	10	3.9	0.09%
Wadi el Biyar Aqueduct	4.7	4	1.18	1.9%
High Level Aqueduct	14	9.4	1.49	0.28%
Low Level Aqueduct	21.5	11.6	1.86	0.14%

A: Actual length of the aqueduct (in km)
B: Straight line between beginning and end of the aqueduct (in km.)
C: Ratio between A and B.

The "heart" of the system is **<u>Solomon's Pools</u>**, three reservoirs which descend in stair-step fashion down the Artas Valley just southwest of Bethlehem **[PHOTO (L): aerial view looking east]**. They are monumental and quite astounding, with a combined surface area equal to more than 4 football fields and a capacity of over a quarter million cubic meters **[PHOTO (R): lower pool; human figure (arrow) shows scale]**. The pools serve as a kind of junction or interchange for the system: Besides collecting rainwater from the plains to the west and the output of 2 local springs, the pools receive the water of the two major "veins" and then send it all out through 3 "arteries" (all discussed below). Solomon's Pools were completely refurbished by the British in 1924, when a pumping station was also installed, to send the water through iron pipes to the Old City.

One of the two "**vein**s" feeding Solomon's Pools from the south is the **<u>Biyar Aqueduct</u>**. It is 4.7 km long and descends at a gradient of 1.9% (1:53). Compared to the other aqueducts in the system, it is the shortest, straightest and steepest. It runs roughly parallel to today's Road 60, about 1 km to the east of the road. It actually collected water in three ways: (1) It conducted water from three springs in Wadi Biyar; (2) it collected rainwater from the valley via a series of dams and shafts; and

(3) along much of its length it was constructed as a trench/tunnel hewn down *through* an aquifer layer into an aquiclude. Thus, along the seam between these two strata the aqueduct itself is draining the aquifer—like a long, continuous layer spring—with water flowing in through the tunnel walls! This technique, which the Romans borrowed from the Persians, is seen nowhere else in Israel-Palestine. Built probably in the time of Herod the Great, the Biyar Aqueduct remained in service for much of the next 2000 years. It was refurbished by the British (along with Solomon's Pools) in 1924 and provided water for Jerusalem's Old City until 1967.

Fig. 2b. The 'Arrub aqueduct crossing a cliff south of Solomon's Pools (author).

The other **"vein"** feeding Solomon's Pools is the **<u>Arrub Aqueduct</u>**. It gathered the waters of a group of springs lying between Bethlehem and Hebron and then, following the contours of the ridges and wadis, wound through the Judean hills for an astounding 40 km (a straight-line distance of 10 km), at an equally amazing gradient of only 0.09% (1:1100+)! For much of its length it was a simple channel hewn into the bedrock slopes **[PHOTO ▲]**, plastered and capped with stone slabs. Obstacles were overcome via two methods: (1) tunneling through some ridges and (2) elevating the channel on a stone wall/dam in order to cross wadis. The dating of the Arrub Aqueduct is not certain, but it is a good candidate for the aqueduct mentioned by Josephus for which Pontius Pilate appropriated Temple funds, thereby sparking riots in Jerusalem (*Antiquities* 18). It seemingly was re-built in the Mamluk period and finally went out of service in Ottoman times. (Its great length made it especially susceptible to damage or clogging, unauthorized tapping of the water, and the pilfering of cap-stones.)

One **"artery"** (unrelated to Jerusalem's water supply, and thus only mentioned here) is the **<u>Herodion Aqueduct</u>**, descending eastward from Solomon's Pools, through the Artas Valley, and ending at that desert fortress of Herod the Great; it can thus be dated to the 1st century BCE. It was long thought that its source was the spring of Artas, but further analysis and excavation now show it to be connected to (and fed by) Solomon's Pools.

Another **"artery"** is the **<u>Upper Aqueduct</u>** of Jerusalem. It began at Solomon's Pools, ran northward, close to the watershed line (at a higher elevation than its "Lower" counterpart); it skirted Bethlehem on the west side, closely paralleled today's Hebron Road, and apparently had as its destination "Hezekiah's Pool" in the Upper City. Its length was 14 km, with an average gradient of 0.28% (1:357). Its best-known remains are a still-visible section of stone pipe (a siphon) across a shallow valley near Rachel's Tomb. Based on inscriptions of the 10th Roman Legion on the pipe segments, the Upper Aqueduct was long dated to the Late Roman period, however it is now clear there was an earlier, parallel, high-level aqueduct section (i.e., elevated on arches), an earlier solution to the same topographical problem, i.e. transmission of the water across the valley. Several surviving piers of this high-level section were discovered and documented in the 1980s and '90s but were later removed in a building project. Thus, the Upper Aqueduct is now thought to have been Herodian in its earliest phase, then re-built in the Late Roman period, and it may have gone out of use after the Byzantine era. Overall, it is not well-preserved. No remains have been found from the area of Jerusalem's old railway station northward, except for its confluence with the Mamilla Pool outflow channel, in the direction of the Old City (but it did not feed that pool—the elevation is not

sufficient), and a segment near its terminal end, in front of the medieval fore-wall north of Jaffa Gate.

The Lower Aqueduct

The **"artery"** we are dealing with here is the Lower Aqueduct of Jerusalem, which ran for 21.5 km from Solomon's Pools (765m ASL) to the Temple Mount (735m ASL). In that distance, it dropped a mere 30 meters, for a gradient of 0.14% (1:700+). Put another way, in the length of a football field, the floor of the channel dropped only 14 cm!

The original Lower Aqueduct has now been firmly dated to the Hasmonean period. This is based not only on ceramics and coins related to its construction but also similarities to the water systems of the Hasmonean desert fortresses, including a distinctive type of plaster. Thus, along with one or more of the Solomon's Pools, it is (in its original form) the oldest part of Jerusalem's aqueduct system. It is mentioned a number of places in the Talmud, which says that "an aqueduct ran to [the Temple] from Eitam [a spring located near Solomon's Pools]," and a midrash states that the same aqueduct was destroyed by the *sicarii* during the Great Revolt.

The Route of the Lower Aqueduct:

From Solomon's Pools it leads northward and runs beneath the town of **Bethlehem** through a tunnel, which is mostly blocked today. Reaching the **Armon ha-Natziv** ridge (Jebel Mukkaber/E. Talpiot) it overcame this barrier by means of a **tunnel [PHOTO►]** stretching nearly 400m and punctuated by several vertical shafts.

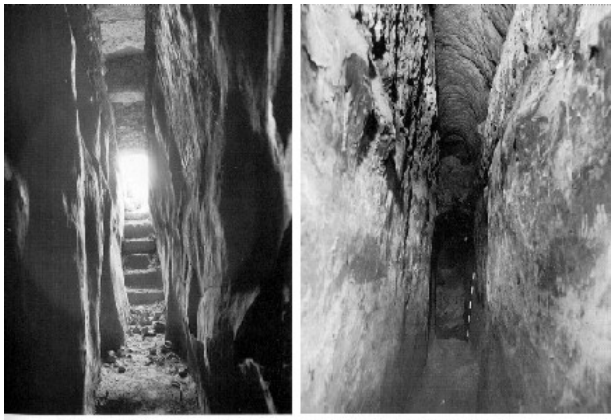
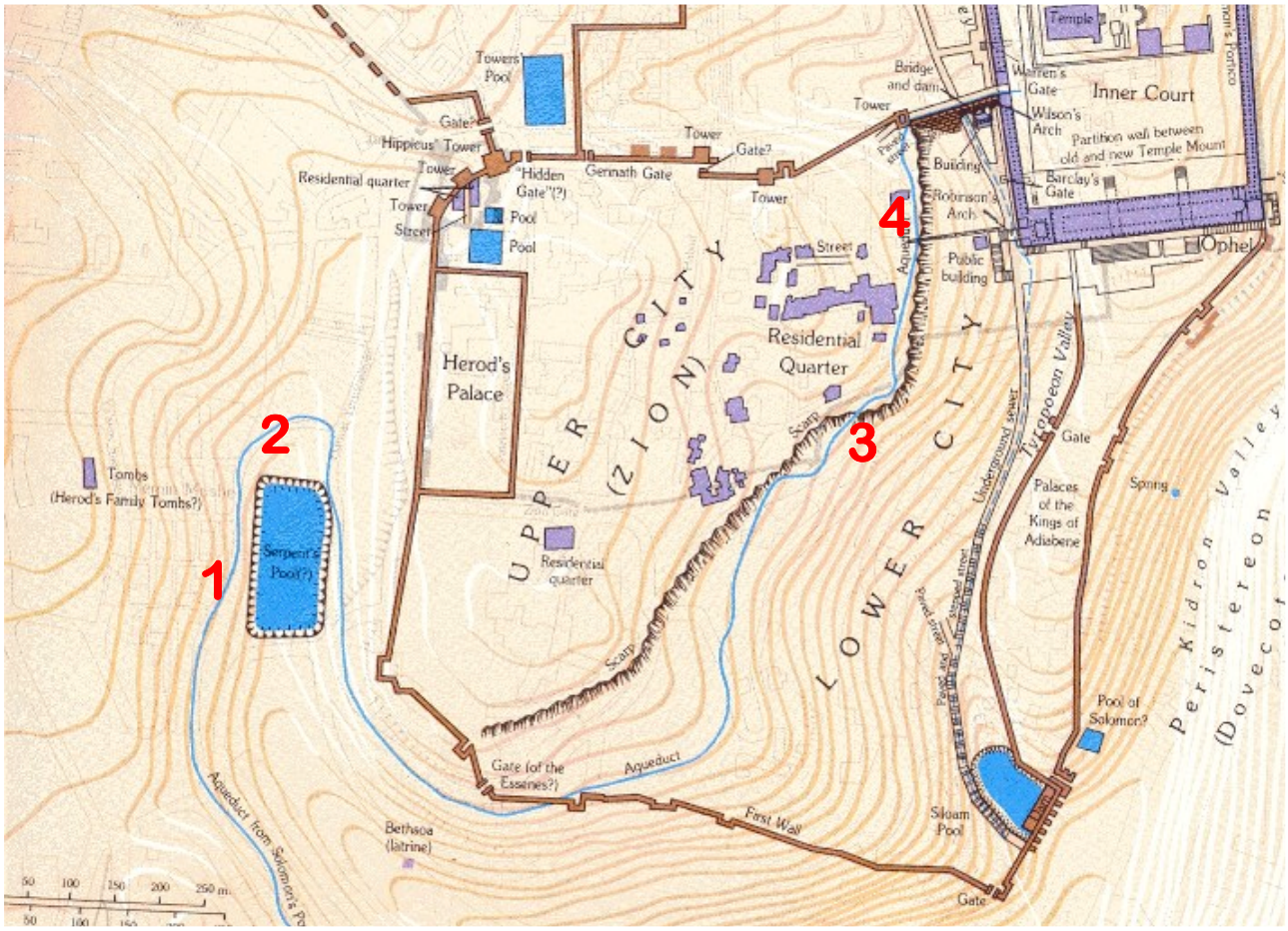


Fig. 6a-b The tunnel of the Low-level aqueduct in Jebel Makabbar ("Armon Hanetziv") (E. Talpiot): interior view near the Sentrance (left) and further inside (right) (Z. Radovan).

The channel emerges from the tunnel just east of and downslope from today's **Haas Promenade**, continues below the **Sherover Promenade [◄PHOTO]** and then across the slopes of **Abu Tor**, to here—the western slopes of the Hinnom Valley. (NOTE: Many of the aqueduct remains in the area of Armon ha-Natziv, the Tayelet, and the Peace Forest have been preserved and marked: At the beginning of the Goldman Promenade one of the tunnel shafts has been exposed, with an interpretive installation; in a park across the street to the south, centered on another shaft opening, is an interesting mosaic map of the whole system.)

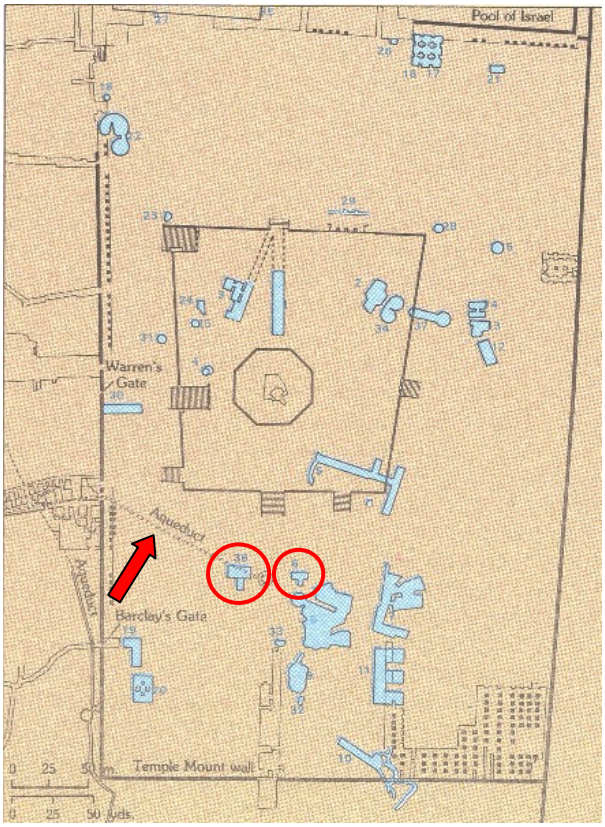
From here, **Mishkanot Sha'ananim**, the Lower Aqueduct continues northward past the Sultan's Pool, and many remains of this section can still be traced with a little effort. North of the Sultan's Pool it then **traverses the Hinnom Valley on an arched stone bridge**. This bridge (the Mamluk version, complete with a dedicatory inscription) was visible into the early 20th century **[PHOTO, 1880s►]**, but was then totally obscured by modern grading and landscaping. (Note: As of 2010, two complete arches near the western end of the bridge were exposed once again in an infrastructure project; the announced plan is to uncover the entire bridge starting in 2011.)

The aqueduct continues around the **slopes of Mt. Zion** and then beneath (outside) the present-day city walls **[left PHOTO ▼]**. Entering the Old City west of Dung Gate, it proceeds through today's **Jewish Quarter**, where portions are preserved along the scarp of the Western Hill (Josephus' "Upper City") opposite the southwestern corner of the Haram al-Sharif (Herodian Temple Mount) **[right PHOTO; note tall, rock-hewn channel and later ceramic pipes▼]**.



▲ The map above shows the route of Jerusalem's Lower Aqueduct in its 1st century context, from the west bank of the Hinnom Valley (left), through the city (center), to its destination on the Temple Mount (upper right). Numbers indicate location of visible remains illustrated here: 1 – Reference segment at Mishkenot Sha'ananim; 2 – Mamluk bridge across Hinnom Valley; 3 – sections outside the south wall of the Old City; 4 – Tall hewn channel opposite southwest corner of the Haram/Temple Mount.

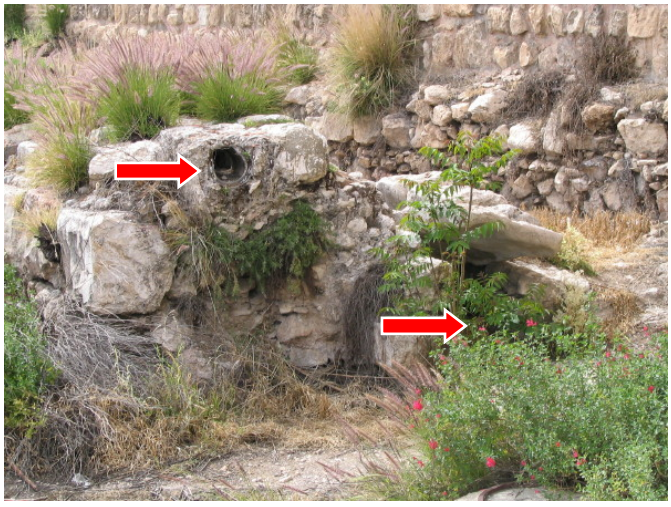
Via the **Wilson's Arch bridge,** the Lower Aqueduct led onto the **Temple Mount** to its ultimate (original) destination, the **cisterns beneath the Haram platform**. The 19th century explorers Conrad Schick and Charles Warren demonstrated that the Haram is pockmarked—akin to a Swiss cheese—with numerous water reservoirs and channels, and their mapping and numbering system still provide our only scientific knowledge of these spaces. **[SEE PLAN►]** They identified a water channel leading from Wilson's Arch **[ARROW►]** in the direction of two particular cisterns, numbers 6 and 36 **[CIRCLED►]**.



Very nearby is the largest of the Temple Mount cisterns, the one the explorers dubbed "**The Great Sea**." Accompanying Warren in 1869, the English artist William "Crimea" Simpson sketched this cavernous reservoir by the light of a burning magnesium wire, and later produced this **watercolor ►**. It is still not known whether (or how) these various cisterns might be connected.

<u>Alterations to the Lower Aqueduct</u>:

Starting at Armon ha-Natziv and running all the way into today's Jewish Quarter there is **a second, parallel channel** constructed at a slightly higher level. (This is not to be confused with the "Upper Aqueduct.") In some places it is a separate, adjacent channel **[PHOTO, outside Old City walls west of Dung Gate►]**, and in others, like here in Mishkenot Sha'ananim, it exactly overrides and obscures the older Hasmonean channel. Thus, the original, lower channel was



rendered forever useless. This shows clearly that the destination and uses of the water changed over time. A good guess for this rebuilding is the **Byzantine period**, when Jerusalem was burgeoning and the Temple Mount, by all accounts, lay unoccupied and largely forgotten. A drawing of Conrad Schick in fact shows this higher channel passing very near the top of the great vaulted cistern of the Nea Church, one possible destination for the water.

In the **Early Islamic and Crusader** periods, the water was probably once again directed to the Temple Mount via Wilson's Arch. At the southwest corner of the Temple Mount, the large horizontal grooves cut into the Herodian masonry probably held pipes which, in the Omayyad period (660-750 CE), conducted at least some of the water to the large palaces or pilgrim hostels situated there.

The aqueduct was restored and rebuilt by the **Mamluks**; their arched bridge crossing the Hinnom Valley was visible into the 20th century (see photo above), was then buried, and now (as of 2010) is being exposed once again.

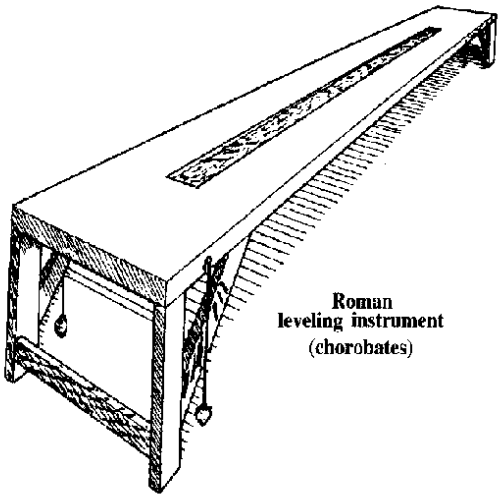
The **Ottoman Turks** reconstructed the Lower Aqueduct along its entire length, laying a closed ceramic pipe **[PHOTO, above]** into the existing channel in the 1500s. The pipe made the aqueduct more vulnerable to blockage, but it continued in use, off and on, into modern times.

In **1902,** the Ottomans bypassed most of the ancient Lower Aqueduct (including the stretch seen here) by constructing a **shunt of iron pipe** on a more direct line from Bethlehem to the Old City. This pipeline never worked well, however, until the British installed pipe all the way from Solomon's Pools and built a pumping station there in 1924, a system which continued to supply water to the Old City until 1967. The partially-ruined pumping station structures, with much of the original apparatus still in place, are still visible.

How Did They Do It?? — A Few Words from Vitruvius (1st cent. BCE)

Vitruvius, ***On Architecture,*** **Book VIII** (extracts):

"[Of the various **levelling instruments**] the ***chorobates*** is the best, a rod about twenty feet in length, having two legs at its extremities of equal length and dimensions, and fastened to the ends of the rod at right angles with it; between the rod and the legs are cross pieces whereon vertical lines are correctly marked, through which correspondent plumb lines hang down from the rod. When the rod is set, these will coincide with the lines marked, and shew that the instrument stands level. [Alternatively], let a channel be cut on top of the rod five feet long, one inch wide, and half an inch high, and let water be poured into it; if the water touches each extremity of the channel equally, it is known to be level. When the *chorobates* is thus adjusted level, the declivity may be ascertained."



"If [water is to be conducted] in channels, the structure must be as solid as possible, and the bed of the channel must have **a fall of not less than half a foot to a length of one hundred** ... If hills intervene between the city walls and the spring head, tunnels under ground must be made, preserving the fall... The **distance between the shafts** over the tunnelled part is to be **one hundred and twenty feet**."

NOTES: (1) Vitruvius specifies a gradient of not less than 1:200, yet some of the aqueducts in the Solomon's Pools system have average gradients in the range of 1:350, 1:700 and even 1:1100—That's engineering! (2) Vitruvius' 120 Roman feet for the spacing of the shafts equals 35.5m; the spacing of the two northernmost shafts of the Armon Ha-Natziv tunnel match this quite closely, at 36.7 and 37.3 meters.

Bibliography

The Aqueducts of Israel (Journal of Roman Archaeology Supplementary Series, 46, 2002). [This work has been issued as a monograph by other publishers as well, in both Hebrew and English.]
Articles:

- "A Survey of the Aqueducts to Jerusalem" by Amihai Mazar, pp. 210-244.
- "The Low-Level Aqueduct to Jerusalem: Recent Discoveries" by Ya'akov Billig, pp. 245-252.
- "New Data for Dating the High-level Aqueduct and the Wadi el-Biyar Aqueduct, and the Herodion Aqueduct" by David Amit, pp. 253-266.

New Encyclopedia of Archaeological Excavations in the Holy Land (Israel Exploration Society / Carta), Vol. 2, "Jerusalem," pp. 746-7, 766.

Jerusalem: A Walk Through Time, Vol. 1 (Yad Ben Zvi, 1999), pp. 90-100.

"Solomon's Pools (Berekhot Shelomo)," in ***The Holy Land****: An Oxford Archaeological Guide from Earliest Times to 1700*, 4th Edition (Oxford University Press, 1998) by Jerome Murphy-O'Connor, pp. 425-428.

"The Aqueducts of Jerusalem" by Amihai Mazar, in ***Jerusalem Revealed: Archaeology in the Holy City 1968-1974*** (Israel Exploration Society, 1973), pp. 79-84