Chapter 5: Irrigation techniques and installations

5.1 Introduction

Irrigation plays a key role in any agriculturally-based society in semi-arid areas, such as the Near East. Irrigation techniques were long established in this region prior to the arrival of the Romans (Chapter 2.3). Therefore, some of the questions ideally to be addressed in this study are whether the Romans contributed any new techniques to the region or whether irrigation methods remained largely unchanged from the pre-Roman into the Roman periods. In addition, did administrative changes in the late Roman period make any impact on irrigation in the region? Solutions to these questions are hampered to some extent by problems concerning levels of resolution in dating the installations and structures associated with irrigation systems.

The techniques and approaches to irrigation will be analysed in relation to their environmental and hydrological setting, which is an important governing element of their use and distribution. Therefore, the installations will be discussed in the following categories: river-fed irrigation; aquifer-fed irrigation; floodwater farming; spring-fed irrigation and well and cistern garden cultivation. Attention will be paid to technological aspects of the installations as well as to their geographical distribution. In addition, the irrigation techniques of the Near East as a whole will be compared to other arid areas of the empire such as North Africa.

5.2 River-fed irrigation (Gazetteer 2)

Water for irrigation was taken from rivers to the land to be irrigated via irrigation channels (sometimes referred to as canals). Irrigation channels have been distinguished from aqueducts where the channel was wider than 1 m and/or does not appear to have fed a settlement.

In our region and period, 33 irrigation channels tapping rivers at 19 sites have been recorded (Gazetteer 2). All of these sites, with the exception of Damiyah, are in Syria. Although Syria has several rivers that are particularly well suited to irrigation channel digging, for example the Euphrates and its tributaries, it is possible that this distribution reflects a research and publication bias. We might expect to find other irrigation channels in relation to other perennial streams in the region in the future.

The irrigation channels in Syria concentrate in the area around the Euphrates and its tributaries with a second, lower concentration in the Damascus area [Fig. 5.1]. Several of these irrigation channels flowed within the *territoria* of late Roman fortresses such as Barbalissos, Callinicum and Circesium. These fortress cities were in areas below the dry-farming precipitation threshold and therefore irrigation channels were vital for their existence, as they could not support a significant population without the use of this kind of irrigation method [see Fig. 1.6].[1]

Irrigation channels tapping the river directly would not have been possible from the Orontes River as the river valley is too deep. Here irrigation channels would have had to have been fed by *norias* or, as at Homs, to have been taken from a dammed reservoir. Such tapping techniques would not have been restricted to the Orontes River. Diverting water into an irrigation channel from a section of river in a deeper channel using a *noria* has been postulated for the ?Islamic irrigation channel at Callinicum on the Euphrates. Dams at the offtake point of irrigation channels have been recorded or inferred from place-name evidence at seven sites on the Khabour River [Nahr Dawwarin (Tell Seker – see below), Haseke (two), Thannouris and #619/620 Tel Dibs/Thallaba (three)] and one on the Euphrates [Auzara].[2] This suggests that the Khabour River, in particular, was well suited to the construction of irrigation channels by means of derivation dams at the offtake points.

Of these 33 irrigation channels, 27 can be attributed with some certainty to our period (see Gazetteer 2). The highest numbers (c. 70%) seem to occur in the late Roman period with 11 attributed to this period with a high level of confidence [Dausara, Circesium, Haseke (five), Homs (three) and Nahr al-Abbara/Nahr Turkman] and a further 9 with a lower level of confidence [Barbalissos, Dibsi Faraj, Sura, Auzara (three), Damiyah, Tell Tamer and Thallaba]. Another irrigation channel off the Khabour River (Nahr Dawwarin), probably constructed in the Babylonian period, may have been restored in the Roman period as indicated by archaeological and papyrological evidence (see below).[3] Three other irrigation channels around the Damascus area may date to the late Roman period, but this

[1] Decker 2001, 98.
[2] Welles 1937; Lauffray 1983, 54; Decker 2001, 103.
[3] Lauffray 1983, 51.

date is suggested with a low degree of confidence.[4] Three irrigation channels have been attributed with a high level of confidence to the Roman period [Lebwe, Tel Dibs (Al Breij) and Thannouris], one seems to have functioned during the Roman period, but was probably cut at an earlier date [Sahlan-Hammam: see below] and one irrigation channel might be Roman in date [Tell Agaga].

The Nahr Dawwarin irrigation channel flows by Tell Seker, which was re-occupied during the Roman period; this re-occupation may have been the stimulus for the restoration of the irrigation channel.[5] In addition, a papyrus recording a bill of sale from AD 227 makes mention of an irrigation channel in land near Tell Seker:[6]

15 ...γείτονες τῆς αὐτῆς

16 χώρας ἀπὸ μὲν ἀνατολῶν κανάλιν ὕδατος καὶ Ἀβούρα ποταμός,...

‘The neighbours of this same parcel are as follows: on the east a water channel and the Khabour River…’

It cannot be known whether the irrigation channel in the text is the same as the Nahr Dawwarin, but it is a tempting possibility. What is clear from the text is that irrigation channels were in use in this area during the Roman period. Furthermore, the place names referred to in the text are significant. Three of the place names (the village the seller is from, the location of the witnessing to the sale and the parcel of land being sold) all refer to a dam or dams: Σαχαρηδααουαράη ‘White Dam’ [lines 2 and 8], Σαχάρη ‘Dam’ [line 5] and Ζαιραδασαχαράη ‘Zaira Dam’ [lines 3 and 10]. As noted above, derivation dams on the Khabour River may have been relatively common-place.

Little has been recorded about the form and design of these irrigation channels as few of them have been excavated. One exception to this is the Sahlan-Hammam channel in the Balikh valley (see Chapter 2.3). Excavation of this 6 m wide channel revealed that

4 Lauffray 1983, 55.
5 Decker 2001, 104.
6 Dura Papyrus 101; Welles 1937; Decker 2001, 104.

rolled sherds and numerous freshwater molluscs lay on the base of the channel, which must have conducted a vigorous flow of water.[7] Four trenches were dug through the channel on a north-south orientation, but none was dug across its entire width and so, unfortunately, the profile of the channel was never exposed fully in cross-section [Fig. 5.2].

The widths of other irrigation channels have only been recorded at two other sites: the Sfaya channel at Thannouris was 3 m wide and the channel at Nahr al-Abbara/Turkman was between 5 m and 8 m wide.[8] The latter channel also featured large limestone blocks (0.5 m – 1 m long) that were positioned every 0.5 km – 1 km; these probably functioned as sluices along the channel's course.[9] Limited data were also available on the area of land irrigated by such irrigation channels; four sites irrigated areas of between 3,000 hectares and 12,000 hectares [Callinicum, Lebwe, Tell Tamer and Thallaba];[10] this illustrates how substantial these systems could be. The irrigation channels in the environs of Damascus irrigated significantly smaller areas (between 60 to 150 hectares).[11] The irrigation channels from the Homs dam fed the agricultural land around Homs as well as the gardens of Homs; these were supplemented by the urban aqueduct from this dam (see Chapter 6.3.2). Analysis of the known lengths of these irrigation channels does not show any statistically significant pattern (Table 5.1 and Gazetteer 2).

Table 5.1: Known lengths of irrigation channels in the Near East.

Length of irrigation channel (km)	Number of irrigation channels
1-5	2
6-10	0
11-15	3
16-20	2
21-40	2

7 Wilkinson 1995; Wilkinson 1998a, 69-71.
8 Lauffray 1983, 61; Wilkinson 1998a, 68-9; Decker 2001, 103.
9 Wilkinson 1998a, 68-9.
10 Mouterde and Poidebard 1945, 150-1; Lauffray 1983, 53, 60-1; Decker 2001, 103.
11 Tresse 1929, 468-9.

5.3 Aquifer-fed irrigation (Gazetteer 3)

Aquifers were able to provide water for irrigation (as well as for use in urban contexts) by the use of qanat technology. A qanat is a subterranean gallery that taps an aquifer, usually located in a hillside or valley side, and leads it to lower-lying ground using gravity flow.[12] A qanat site is identified in plan as a line of circular spoil heaps [Fig. 5.3]. These heaps derive from the construction method of a qanat, which comprises the digging of vertical access shafts at frequent intervals and tunnelling between them.

Qanats have interested researchers in ancient water supply techniques for several decades and a substantial bibliography has built up around them, including several studies of qanats in the East.[13] Questions concerning their origin have already been discussed in Chapter 2.3. The qanats in our region have been treated with special attention as they may provide clues concerning the diffusion of this technique: a particularly thorny subject in qanat studies.

A further reason for the increased interest in qanats in recent decades is their potential to address modern problems of water supply in the Middle East.[14] This has lead to several useful studies on qanats in the Middle East, for example the work by Joshka Wessels at Shallalah Saghira. Work such as this has lead to interesting observations on the workings of qanats, for example the clearing of the qanat line in Ghor Nimrin/Kibid showed that the chief characteristic of the flow was a greatly delayed peak where there was a long time-lag between the rainfall and the arrival of water on the marls of the Ghor.[15]

Qanats are particularly well suited for use in areas where surface water supplies are sporadic as the groundwater provides a resource that can be tapped throughout the year even if there are seasonal fluctuations in the water table.[16] There is a strong correlation between the location of qanat sites and rainfall, evapotranspiration, topography and geology.[17] In the East alluvial aquifers occurring along major river valleys and beneath alluvial fans at the margins of highland areas and larger wadis coming out of mountains are

[12] Wilson 2003a, 133.
[13] Key works include: Aisenstein 1947; Goblot 1979; Kobori and Endo 1980; Beaumont 1989; Bonine 1989; Honari 1989; Lambton 1989; Ron 1989; Kobori 1990; Safadi 1990; Lightfoot 1996; Lightfoot 1997; Briant 2001; Wilson 2003a.
[14] See for example: Safadi 1990.
[15] Ionides and Blake 1939, 169.
[16] Beaumont 1989, 13.
[17] Lightfoot 1996, 327-9.

widespread (see Chapter 1.3).[18] These aquifers provide water at a shallow depth and are therefore ideal for qanat construction. Their locations explain the major distribution patterns of qanat sites across the area: Lower Jordan Valley, the western band between Damascus and Aleppo and the Palmyra area [Fig. 5.4]. In Syria 90% of qanat sites lie within 25 km of upland areas and 75% lie completely within piedmont slopes at elevations of 500 – 1000 m [Fig. 5.5].[19]

Similarly, all of Jordan's qanats were constructed in the piedmont zone because of the greater quantity and better quality of groundwater in that zone.[20] The majority of Jordanian qanats (across all periods) tap shallow aquifers of 5 – 20 m depth with higher transmissive flow (i.e. where water can flow more easily through an aquifer) [Fig. 5.6].[21] These conditions are ideal, but rare in Jordan, so the pattern seems to show deliberate and knowledgeable exploitation of these zones by the qanat builders. The geology of the steppe and desert regions of Syria (and Jordan) has an added benefit: calcium carbonate and silica form impervious layers beneath permeable marly and calcareous formations nearer the surface, which means that the aquifers can be recharged seasonally.[22] In contrast, no qanats are found in the impermeable basalt regions of Syria and northern Jordan. In addition, the majority of qanats in Syria are constructed within areas at or below the 500 mm isohyet and in areas of the country with the largest discrepancy between precipitation and potential evapotranspiration [Fig. 5.7].[23]

The qanats varied in length from 100 m to 9 km with half of the qanats whose lengths are known (5) lying in the 1 km – 5 km bracket (Gazetteer 3). This fits with a general pattern seen in qanats across the world: in a survey of more than 2,000 qanats it was shown that 81% were less than 5 km in length.[24] The shafts were spaced at intervals of between 10 m and 22 m and mother wells varied in depth from 6 m [#652 Yotvata] to as deep as 30 m [#612 Palmyra]. The tunnel cross-sections varied in width from 0.4 m to 1.0 m and in depth from 1.6 m to 2.5 m [Figs 5.9-11].

[18] Beaumont 1989, 13-15; Lightfoot 1996, 328.
[19] Lightfoot 1996, 328.
[20] Lightfoot 1997, 443.
[21] *Ibid*. 443-7.
[22] Lightfoot 1996, 329; Lightfoot 1997, 443.
[23] Lightfoot 1996, 327.
[24] Beaumont 1989, 23.

Five of the qanats featured sections with masonry revetment: Amsareddi, Birke de Qdeym, Taibe, Andarin and Palmyra. The shafts for two of the qanats in the Taibe oasis were constructed from masonry and the ceiling of the tunnel of one of these qanats also received support from additional ashlar masonry.[25] The Umm al-Omi qanat at Palmyra had nine steps of marble and an entrance gate with a sculptured arcade [Fig. 5.12];[26] this qanat exhibits the most architectural decoration of any qanat in the east.

Nine of the qanat systems ended in built reservoirs [Figs 5.13-14]: Lebwe/Qnayé (70 m x 70 m), Amsareddi (c. 60 m x c. 60 m), Andarin (61 m x 61 m x 3 m and 61 m x 61 m), Udhruh, Ghor Nimrin/Kibid, Ain Evrona/Dafieh, Birke de Qdeym (62 m x 62 m x 3 m) and Taibe (55 m x 20 m). Calculations assuming a depth of 3 m for these reservoirs give capacities of 11,532 m^3 [Birke de Qdeym], 11,163 m^3 [Andarin] and 8,478 m^3 [Amsareddi]. It would have taken the Amsareddi qanat c. 6.5-8 days (i.e. 24 hour periods) to fill its reservoir, which would have irrigated c. 20 ha.[27] No information was provided on flow rates and/or reservoir dimensions of other qanats, so it has not been possible to calculate how long it would have taken to fill these tanks.

Sluices were found at the inlet and outlet points of the north-western reservoir at Andarin.[28] Before the qanat reached the inlet point of this reservoir, a branch channel led water to the surrounding fields, which suggests that the reservoir may have stored water for purposes other than irrigation (see Chapter 10.4). The outlets at the Andarin reservoirs, the southern one of which may have been a fishpond, were c. 1 m above floor level. The Birke de Qdeym reservoir had a large settling tank upstream of the inlet.[29] At the outtake point there was a sluice that directed the water to the surrounding land. A derivation channel was located upstream of the reservoir so that the reservoir could be cleaned while the qanat was still flowing; this was also a feature of the reservoirs at Andarin. There was also a channel (0.6 m wide x 0.3 m deep) that ran around the structure c. 0.25 m above the intake level

[25] *Ibid.* 115; Kobori and Endo 1980, 54-58, 61-2.
[26] Wood 1753; Bounni and As'ad 1989, 130; Kobori 1989, 9; Kobori 1990, 322.
[27] This is calculated on a flow rate of 12-15 l/s. Two flow rates are given in Mouterde and Poidebard 1945, 119 for this qanat: 5 m^3/hr and 12-15 l/s (equivalent to 43.2 -54 m^3/hr). If the first figure were used, it would take c. 70 days to fill the reservoir, which seems excessively long. The second figure has therefore been used in preference. Also, the second figure is more in line with the outflow from the Ghor Nimrin/Kibid qanat (36-72 m^3/hr). It is possible that '5 m^3/hr' is a publication error and should read '50 m^3/hr'.
[28] Decker 2001, 118-9; Mouterde and Poidebard 1945.
[29] *Ibid*. 120-1.

(probably to remove excess water) and large circular platforms of unknown function in its corners [Fig. 5.13]. At Lebwe/Qnayé the reservoir fed water to a walled enceinte [Fig. 5.14].

The date of the introduction of qanats to this region is important in qanat diffusion debates. Of 46 qanat lines over 19 sites, however, only 4 lines can be dated with a high degree of confidence within our period; 13 lines can be dated with a medium degree of confidence and over half of the lines (29) can be dated with only a low degree of confidence [Gazetteer 3].

A radiocarbon date has recently been obtained for one of the reservoirs at Andarin. Provisionally, this seems to date the reservoir to the 6th century AD; the excavators hope to take more radiocarbon samples in order to gain a more accurate and reliable date.[30] Another of the relatively-securely dated lines at Shellalah Saghira in Syria has been given a late Roman date on the basis of an inscribed cross in the tunnel;[31] it is, however, possible that this cross does not belong to the original construction phase and therefore the qanat could be earlier.

The dating of the line at Anasartha/Al Hammam is based on an inscription from a large basalt lintel found 400 m north of the qanat shafts and at the eastern extremity of the ruined site:

Συνφυής τῷδη τῷ παντὶ ἐξ ἄκρας στο[ρ]εν[νύναι πέδιον (?) καὶ ἀλλάξαι]

τῷ ὑγρῷ το ξηρόν· θείῳ νεύματι τῇ πη[γῇ πέφυ]κε κρα[νάη ἦδ']

οὐσία, πρόσφορον πρὸς ὑγίας φάρ[μακον ἐσ]τῶσιν τύ[φειν] (?)

[Ῥε]ῖθρον χαριζόμενον εὑρών, Γρ[ήγοριος (?) κομ]ιδὴν ἔρκσ[ε]ν, οἷα

τῇ πατρίδι ὁ νοσαρθῶν προσῆκον τα[θῇ ῥόος β]ί(ου) καὶ ἀσυλίας

[τὸ πᾶ]ν δὴ ἔργον πρὸς ἥβην ἐγειρίστη .... ἰνδ(ικτιῶνος) ιβ.

30 Marlia Mango pers. comm.

31 *Ibid.* 122.

‘It is natural in this universe for things to roll to the plains from the summits and for dry to follow humid: by divine good will, fallen from this source, out of this rock came the power to exhale vapours, offering a salutary remedy suitable for passers-by. Having discovered an abundant source, Gregorios worked on its capture, which extended easily to his homeland the stream of life and prevention against illnesses. All this work was carried out in [the year of] the 12th indiction.’[32]

It is thought that Gregorios must be Gregorios Abimenos, a rich Arab, who in AD 604 restored the city gates and possibly the citadel at Hanaser.[33] This dates the inscription securely to this period.

Other attempts have been made to date qanat lines using written documentation. The water from the qanat systems at Hierapolis, Syria may have been used for the cult and sanctuary of Atargatis, for which water was an essential component. It has been proposed that this theory is supported by a reference to a sacred lake in Lucian on the basis that this lake may have been fed by a qanat.[34] If this is the case, this would provide an exceptionally early date for qanats in Syria as Lucian was writing in the early 2nd century AD; such a hypothesis is, however, rather tenuous and unreliable.

Wood also notes Palmyrene inscriptions, but none in any other language on the Umm al-Omi qanat at Palmyra.[35] This is used as an argument for an early date for qanats at Palmyra (i.e. before the late Roman period), because otherwise one would expect to have found Greek inscriptions as well. Further work on these (unpublished) inscriptions would be very useful given the potential importance of the date of these qanats (see below).

The problems associated with dating these systems centre on problems of longevity and finding (dateable) artefacts from key contexts. In the absence of epigraphic or literary evidence, qanats are virtually impossible to date, except by spatial association with a settlement, which may be problematic, or by fortuitously preserved stratigraphic relationships.[36] As is usual, attempts have been made to date the lines by using settlement evidence with varying degrees of success. Lightfoot notes that there is a high level of

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[32] Text and translation: Mouterde and Poidebard 1945, 207-8.
[33] *Ibid.*
[34] Egea Vivancos: poster presentation at ‘Cura Aquarum in Ephesus’, October 2004.
[35] Wood 1753; Crouch 1975, 166.
[36] Lightfoot 1996, 324.

correlation between qanats and Roman/late Roman sites (termed Roman-Byzantine by Lightfoot) with 40% being found within or adjacent to Roman-Byzantine towns or fortified villages and 50% in the immediate vicinity of smaller Roman-Byzantine outpost or guardhouse ruins. This looks like good evidence for Roman-Byzantine dates for qanats in this area and is particularly convincing at Qdeym, which would otherwise have had severe problems with water supply. Lightfoot does, however, supply a *caveat* over these data as he also notes that this settlement evidence is not conclusive and that some of the qanats equally may have been built for use at Islamic sites in the area.[37]

Kobori and Endo attempted to date one of the lines at Taibe oasis [#624] by radiocarbon dating a piece of wood that may have supported the ceiling of the tunnel; the wood was not *in situ*, however, and therefore any date derived from it is unreliable.[38] Various attempts have been made to date qanats by pottery, but the recovered assemblages tend to be mixed and without clear context, so it is hard to attribute a secure date to the assemblage: for example we are told that Evenari and Aharoni found 'ancient Persian and Roman potsherds' in abundance 'near and inside' the qanats investigated in the Arava valley.[39] It has been said recently that no qanats in Israel pre-date the Islamic period, for example Avner claims that the qanat at Yotvata was stratigraphically later than the late Roman period, but it is not made clear why.[40] Finally, both Lightfoot and Kobori have shown the dangers of using oral information about the date and history of qanats.[41]

This situation has clear consequences for any conclusive assessment of where the East lies chronologically in the transfer of qanat technology. The evidence seems to point to the fact that qanats were present in the area by the late Roman period. So, we can posit that qanats were introduced during the late Roman period, the Roman period or the pre-Roman period. As discussed in chapter 2.3, there is no positive evidence to suggest that qanats were in the region in the pre-Roman period. If we claim that qanats were introduced during the Roman period, we need to consider the source of this introduction. Within the empire, Egypt would be the most likely contender, but qanats were only used to a limited extent in outlying areas. It seems more likely that the influence would come from Persia via desert

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[37] *Ibid.*
[38] Kobori and Endo 1980, 66; Lightfoot 1996, 324.
[39] Evenari *et al* 1982; Ron 1989, 219.
[40] Avner 2001-2, 410.
[41] Kobori and Endo 1980, 66; Lightfoot 1996, 324.

trade where qanats were in common and widespread use. Furthermore, and most significantly, this would make qanat technology an example of a technology that was introduced into and disseminated around the Roman Empire from the east. If desert trade was the carrier of this technology, the date of the qanats at Palmyra becomes very important and a thorough survey of these systems and their inscriptions must become a priority for research into qanats. Alternatively, qanat technology may have been transferred from the Arabian peninsular, presumably also via desert trade. Reluctantly, however, we must agree that any such theories can only be supposition for the time being.

5.4 Floodwater farming (Gazetteer 4)

Work on field systems in the Near Eastern region has seen an increase in recent years; this must be linked directly to an increase in field survey projects over the past decade that have focussed on understanding the greater landscape of the region, for example the Wadi Faynan project in Jordan and the Homs Regional Survey in Syria.[42] Projects such as these, which are based on a strong methodological framework and make good use of innovative techniques and computer technology, have revealed, or are in the process of revealing, large amounts of useful and reliable information on field systems in the Near East. Work of this calibre is needed desperately in the East as the advent of more intensive modern farming techniques, in particular the liberal use of bulldozers, is rapidly destroying much of the archaeological evidence for ancient, irrigated landscapes. Extensive work has also been undertaken in the Negev, but without making use of the more innovative techniques that make the Wadi Faynan and Homs projects stand out.[43] As several sites were looked at in the Negev, they are referred to here under their individual names, rather than under the collective term ‘Negev’.

A comprehensive, in-depth study of such floodwater farming techniques, in particular the Wadi Faynan field systems, has been undertaken recently by Newson.[44] Therefore, rather than repeating this research, what follows will try to highlight some

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[42] Barker *et al.* 1997; Barker *et al.* 1998; Barker *et al.* 1999; Barker *et al.* 2000; Newson 2002; Philip *et al.* 2002.
[43] The main publications on the Negev are as follows: Kedar 1957; Glueck 1959; Mayerson 1959; Mayerson 1960a; Mayerson 1960b; Negev 1974; Kloner 1975; Evanari *et al.* 1982; Rubin 1988; Rosen and Finkelstein 1992; Finkelstein 1995.
[44] Newson 2002.

striking aspects of the systems. One of Newson's main findings is that local topographical aspect was vital when establishing a field system.[45] The following environmental factors in particular governed their establishment: an adequate supply of floodwater; a point suitable for floodwater capture in large enough volumes for agriculture; and a large enough area of land to supply crops for the local population and possibly a surplus for trade. Unsurprisingly field systems were established in locations where they could support settlements.[46] These settlements generally fell into the following categories: small permanent settlements founded by direct governmental authorisation ('powerful establishments' such as Wadi Faynan); large areas of scattered settlements whose inhabitants engage in agriculture, brought about either by colonising policies or by favourable conditions for settlement.

5.4.1 Terrace farming and wadi farming

Irrigation field systems associated with floodwater farming fall broadly into two categories: terrace farming and wadi farming.[47] Terrace farming retards the flow of rainwater and diminishes soil erosion from runoff on sloping topography. Wadi farming is sometimes combined with slope terracing methods and is found in two different forms: tributary wadi cultivation and main wadi cultivation [Figs 5.16-7]. Tributary wadi cultivation, which is used in smaller wadis, ravines and gullies, is characterised by stone walls that traverse the wadi in order to create small plots of land. This technique was also used widely in Tripolitania in North Africa and was studied extensively in the UNESCO Libyan Valleys Archaeological Survey (see section 5.8 below).[48] The walls retard the velocity of the water allowing for deposition of fertile silt on the plots and also raise the water level so that water can spill laterally onto land along the sides of the wadi. In main wadi cultivation dams divert water from the wadi into fields along the wadi banks.

Five sites in the Near East have been investigated as areas of terrace farming (though there must have been many more): Wadi Faynan, Khirbet Abu an-Nasur, Sbeiteh (Shivta), Sumaqa and 'Site 637'. Only Khirbet Abu an-Nasur does not seem to have

[45] *Ibid.* 242-3.
[46] *Ibid.* 243-4.
[47] The following definitions and descriptions are based on Mayerson 1960a, *passim*; Frösen *et al.* 1998, 495.
[48] Barker and Jones 1982; Barker *et al.* 1996.

functioned in conjunction with wadi-farming techniques. Fifteen sites in the east made use of wadi farming.[49] Tributary wadi cultivation seems to have been the favoured type of wadi farming with 10 of the sites functioning on this basis [Wadi Faynan, Rosh Ha'ayyin, Jabal Harun, Nakhl, Zikhron Ya'aqov, Horbat Kohal, Wadi Mshash, Ruheibeh, Jerusalem and Qadesh Barne-a]. Three of these sites [Jabal Harun, Sbeiteh and Kurnub] seem to use both types of wadi farming, though in the case of Kurnub, at least, the types were not used contemporaneously (see below Section 5.4.3). Only three sites functioned solely as main wadi cultivation areas: Diyateh, Nahal Hevron and Sumaqa.

Wadi farming techniques showed varying levels of sophistication and a variety of features were employed in the systems. One of the most complex examples was at Wadi Faynan, where terrace, main and tributary wadi techniques were used.[50] In some ways Wadi Faynan was atypical because of its excellent state of preservation, its large scale and complexity and the high numbers of pottery sherds across its area that helped to refine the understanding of its chronological development.[51] The work at Wadi Faynan focussed on an area referred to as WF4, which was subsequently subdivided into 20 units, which themselves were divided into individual field units [Fig. 5.18]. One of the main reasons behind the success of this floodwater system was the knowledge of how to channel water over long distances over very low angle slopes. In addition, the various methods used were closely tied to the topography and landscape.

Firstly, the predominantly flat, northern half of WF4 was characterised by parallel channels. Trial trenches through these channels illustrated that they were clay-lined and filled by water-lain sediments, which confirmed their interpretation as water channels. They could be split into two principal types [Fig. 5.19]. One type exploited wadi-water through damming and diversion; these were c. 2 m - 2.5 m wide and formed by free-standing walls. The other type redirected overland flow; these were narrower and predominantly formed by a dwarf wall at the foot of a faced terrace. Channels that tapped the main wadi (Wadi Faynan) deviated to the south before continuing west. They appeared to use the velocity of the floodwaters so that flooding was spread into the main area of the field system. The

[49] Wadi Faynan, Rosh Ha'ayyin, Jabal Harun, Nakhl, Nahal Hevron, Zikhron Ya'aqov, Horbat Kohal, Jerusalem, Qadesh Barne-a, Sbeiteh/Nessana area, Wadi Mshash, Sumaqa, Ruheibeh, Kurnub and Diyateh.
[50] The following description is collated from Barker *et al.* 1997, esp. 31-2; Barker *et al.* 1998, esp. 13-16; Barker *et al.* 1999, esp. 276-278; Barker *et al.* 2000, esp. 43-44.
[51] Newson 2002, 226-7; 256.

minor wadis from the south were usually tapped at the confluence of wadi channels to take advantage of the higher volumes of water. Channels here were usually built at 45º to the wadi channel in a herringbone pattern and diverted water into fields on either side [Fig. 5.19, C-G].

On the higher ground on the southern side of WF4 floodwater was captured where three tributary wadis break through the surrounding hills [Fig. 5.20]. The water control in WF4.3 illustrates how water could be directed to certain parts of the field system using a system of sluices (that could be opened or closed) and baffles (stones arranged below a sluice gap to spread water as it flows past), so that water could be prevented from running into the main wadi for as long as possible. The system diverted water at point E (on fig. 5.20) into a long meandering parallel-walled channel that ran north-west. Small sluices on this channel, some with baffles, allowed water into the upper fields (fields 11, 10, 8, 15 and 17). The channel ended at a cairn, where a complex junction (of unclear nature) channelled water to fields to the west (3, 2 and 1), the north-west (22, 20 and 25) and the north (23, 21 and 19).

In WF4.18 at the western end of the field system a further solution was used. Here cross wadi walls were constructed at the confluence of wadis. These walls stemmed the wadi flow and forced water out onto the surrounding fields.

While Wadi Faynan may have been exceptional in its complexity and ingenuity, other sites also illustrated sensitive and sophisticated solutions to floodwater farming. At Nakhl walls were constructed perpendicular to the tributary wadi walls/dams, thus dividing the area into smaller sections that may have been pools or small reservoirs [Fig. 5.21].[52] In addition, three cisterns were recorded in this system (on cistern-fed garden cultivation, see below section 5.5). A reservoir was also associated with one of the diversion dams at Nahal Hevron; no further details were provided.[53]

The system at Wadi Lavan, Sbeiteh was built on two main levels [Figs 5.22-23].[54] The upper level, which was laid out at the same level as the alluvial fan, obtained water from a runoff gully and was divided into 8 subplots (totalling 30,000 m^2). The lower level (totalling 80,000 m^2) obtained water from the wadi itself and was fed by three channels,

[52] Mattingly *et al.* 1998, 332, 334.
[53] Negev 1996.
[54] Kedar 1957, 183; Mayerson 1960a, 34; Evenari *et al.* 1982, 114-118.

which supplied water to different sectors of the lower level. In addition to the three channels, three types of spillway served as drop structures that carried water from the upper terrace to the lower terrace. The three types may represent stages in the development of the system. Type 1 spillways, which were unconnected to stone walls, handled flows of 10 m^3 – 30 m^3 per second and had crest lengths of 30 m – 60 m. Type 2 belonged to diversion systems where only part of the flood was utilized; they had crest lengths of 3 m – 8 m and handled flows of 1 m^3 – 5 m^3 per second. Type 3 spillways were smaller (up to 1 m wide) and handled flows of less than 1 m^3 per second.

5.4.2 Chronology

There seems to have been a general trend towards an increase in floodwater farming in the late Roman period. Unfortunately, the Negev survey suffered from a lack of detailed chronological typologies and so was constrained by a vague temporal framework.[55] Future research should, therefore, look to the Wadi Faynan survey and take more pains to construct at least a relative chronology for particular field systems.

Several changes seemed to occur in systems that were in use over long periods of time, for example at Wadi Faynan and Kurnub. At Wadi Faynan it has been proposed that wadi down-cutting, possibly in the Roman period, made the earlier floodwater farming techniques based on diversion barrages and terracing on upper slopes less effective. In response to this, the emphasis was changed to capture water at lower elevations and to spread it across the lower slopes by means of parallel wall channels.[56] The development of the water management systems at Wadi Faynan was also reflected in other parts of the system such the re-plastered reservoir inlet and the mill, whose upper level consisted of *opus signinum* and the lower level a coarse lime plaster.[57]

Similar problems were faced at Kurnub where the wadi walls that had been sufficient when the wadi was a shallow depression were no longer effective as the wadi cut deeper, with the result that the runoff water ended up being 1 m – 2 m below the level of the floodplain. Therefore, a diversion channel (400 m long x 9.5 m wide) was created that led water to a broad series of terraced fields. At a later date again the diversion channel

[55] Newson 2002, 7.
[56] Barker *et al.* 1998, 24.
[57] Barker *et al.* 1997, 37.

filled with silt and the lower section of the system was converted into a runoff farm where small diversion dams diverted runoff from small wadis into conduits.[58]

These examples illustrate that field systems were not static over time, but rather show diachronic developments and adjustments to their layouts and organisation. Secondly, and most importantly, although an area such as Faynan has been described as a landscape of centralised control and imperialism,[59] some of the developments that occur may not be related necessarily to the social or political milieu in which they take place. More simply they may be related to the environment of which they are part, which itself undergoes modifications. In some cases the changes that we see in the field systems may not mark technological progress or imposition of new ideas, but may be a 'natural' response to changing topographic circumstances. Similar observations were made during the UNESCO Libyan Valleys Survey, in which it was noted that the creation of the field system was a knowledge-based activity that relied on an intimate knowledge of the topography, geology and hydrology of the area to be irrigated.[60]

5.5 Well and cistern-fed garden cultivation (Gazetteer 5)

Evidence for irrigation using water from wells in the Roman and late Roman periods was surprisingly lacking, though one would expect that such a simple technique of accessing water for irrigation of small areas and gardens would have been commonplace. This is probably because the evidence for garden irrigation from wells, rather than drawing water for animals and humans, is frequently ephemeral, such as small mud channels. Recent excavations of *saqiya* installations over wells used in irrigation projects at Yavne Yam and Tel Ashdod suggest that further fieldwork may redress this balance (Chapter 3.6).

The evidence for the use of cisterns in irrigation and garden cultivation has also not been widely published, with the exception of the Monastery of St Martyrius.[61] This monastery (founded in the early 470s AD) featured three garden areas (upper garden: 2,500 m^2; southern garden: 7,500 m^2; eastern garden: 1,000 m^2) that were fed by runoff water stored in cisterns [Fig. 5.24]. The eastern garden, which was the best preserved, was

58 Evenari *et al.* 1982, 112-4.
59 Newson 2002, 257, 264.
60 Gilbertson and Hunt 1996, 224.
61 Damati 2002.

surrounded by a massive masonry wall and had three irregular terraces [Fig. 5.25]. The cistern in this garden received water from two channels that brought runoff water from the ridge and apparently had a capacity of 1,500 m^3 [Fig. 5.25]. No further details, including dimensions, have been published about this cistern, but from the site plan it seems unlikely that the cistern could have been large enough to hold this much water and so may have been significantly smaller. Each terrace had its own plastered pool; these varied in size (2.4 m long x 1.8 m wide (depth unknown); 1.5 m long x 1.0 m wide x 0.4 m deep; 2.8 m long x 2.2 m wide x 1.8 m deep), but all featured a lead pipe that led water from the pool into three square stone basins and then into the irrigation channels. Eight irrigation channels were identified; all were narrow (c. 0.15 m wide x 0.10 m deep) and had apertures at 1.5 m intervals to release water for irrigation of the garden [Fig. 5.26].

Overflow water from the monastery cisterns, directed via rock-cut channels, fed the gardens at Khirbet ad-Deir and Chariton.[62] In the case of Khirbet ad-Deir, this supply supplemented that of the dam/reservoir system, which protected the monastery when the wadi was in flood as well as providing water and soil for the garden. The garden of the Monastery of Euthymius was similarly fed by a combination of cistern and reservoir water.[63] At this site two reservoirs and a cistern cultivated an area of c. 2500 m^2. Dimensions and capacities of the water supply and storage components were not provided for these sites.

5.6 Spring-fed irrigation (Gazetteer 6)

Eight field systems in the East are known to have made use of spring water rather than runoff or wadi water: En Gedi, At Telah, Ein Yalu, Abu Gosh, Nahal Zippori, Wadi al-Nazazat, Emmaus, En Boqeq. This is a surprisingly low number and must represent a publication bias, rather than a genuine low use of such an obvious source of water for irrigation. At En Gedi and At Telah water from spring-fed reservoirs watered terraced and walled fields in the surrounding area [Fig. 5.27].[64] The regular layout of the fields at At Telah, which is uncharacteristic of other field systems in the Near Eastern landscape, points to a highly-ordered system that probably required a large workforce to create. Newson

[62] Hirschfeld 1992, 153, 159.
[63] Hirschfeld 1992, 200. Cyril *V. Euth.* 15, 24.17-18.
[64] Glueck 1959, 201-2; Ofer and Porath 1986, 28-9.

argues that this may point to input from a Roman or late Roman authority.[65] Although unproven, this hypothesis is tempting and does provide some explanation for these uncharacteristic field layouts in the Near Eastern landscape.

The systems at Ein Yalu, Abu Gosh and Emmaus made use of spring flow tunnel technology to access spring water.[66] These systems stored the spring water in reservoirs before channelling it out into the surrounding fields; the reservoir at Ein Yalu, which was heavily restored in the 19th century, has a capacity of 4,000 m^3. The plastered irrigation channels running at the base of the terraces in the Ein Yalu system were controlled by a 'valve' system that allowed for a regulated distribution of the water. The nature of this 'valve' system is not made explicit nor is the date of this feature clear from the report; given the later restorations and additions to other parts of the system, it is possible that these 'valves' were also inserted at a later date. The reservoir at Emmaus stored a significantly smaller volume (30 m^3) and so cannot have served as a long-term storage facility; it may have been used as a drawing-off point for animals or drinking water as well.

There is a common confusion concerning spring flow tunnels and qanats. It has been said, for example, that the urban supply installation associated with the Efca spring at Palmyra should be considered as a qanat [Fig. 5.8].[67] This installation is not a qanat, but rather a spring flow tunnel. Surprisingly, Lightfoot also appears to make this mistake with the tunnels at Abila and Gadara (Umm Qes) in Jordan.[68] Although there are similarities in the construction techniques (both are excavated tunnels designed to extract water by gravity flow), there are crucial differences between the two.[69] Firstly, the origin of the qanat was a well that was turned into an artificial spring. In contrast, the origin of the spring flow tunnel was the development of a 'real' spring to renew or increase flow, following an episode of the water table receding. Secondly shafts, which are essential to qanats, are not essential to spring flow tunnels.[70] Urban spring flow tunnels will be discussed separately in Chapter 6.2.3.

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[65] Newson 2002, 244.
[66] Ron 1966, 113; Gibson and Edelstein 1985, 143; Ron 1985, 168; Hirschfeld 2002a.
[67] Kobori 1989, 8; Kobori 1990, 322.
[68] Lightfoot 1997, figs 2, 3 and 5.
[69] Ron 1989, 231.
[70] *Ibid.* 232-234.

Finally, an almost square building (10.5 m long x 9 m wide), constructed of ashlar masonry, was recorded at the end of the En Boqeq system.[71] This structure may have been a water distribution point because it had one inlet and two, possibly three, outlets that head towards the fields [Fig. 5.28]. This may be an example of a rural installation taking ideas from urban installations, in this case the urban concept of the *castellum divisorium* (see Chapter 7.2.1). No other examples of such a structure are known elsewhere in the East.

5.7 *Teleilat al-anab*

A third type of structural remains, *teleilat al-anab,* 'grape mounds', has also been associated with irrigation in the Near East. These are rows of artificially-created mounds of soil mixed with gravel, covering areas of between 2 to 2,500 hectares that are usually found on *hammadas* (stony desert areas) fairly close to urban sites; examples are to be seen at Auja, Sbeita, Mishrefa and Abda.[72] Mayerson has distinguished three types of heap: conical, ridge and 'flowerpot'.[73] Conical mounds range from 1.5 m – 3.5 m in diameter and from 0.25 m – 0.5 m high; they are usually arranged in rows 2 m –5 m apart [Fig. 5.29]. Ridge mounds are long strip heaps that do not follow the contour of the slope (and therefore are not terrace walls); they are usually 2.5 m – 3 m wide at the base, 0.15 m – 0.25 m high and spaced 6 m – 10 m apart [Fig. 5.30]. These two types can be found on the same slope. 'Flowerpot' mounds are only found on very stony *hammada* with little or no soil cover and are circles or rectangles of stone with gravel and soil on the inside [Fig. 5.31]. They are usually 2.5 m – 3 m in diameter, 0.5 m high and are either arranged in rows at 15 m intervals or in an irregular pattern.

Debate on the purpose of these curious structural features has continued unabated since the late 1950s.[74] Kedar suggests that the removal of the stone into heaps accelerated soil erosion in order to create soil beds for agriculture. This has been rebuffed successfully by Mayerson and Evenari *et al.* who show that the heaps were constructed after not before the valley agriculture developed, that it is unlikely that the implicit assumption that wadis in

[71] Fischer and Shacham 2002, 407-8.
[72] Mayerson 1959, 20.
[73] The following description is based on: *ibid.* 21-2.
[74] The following theories and arguments are all discussed in: Kedar 1957; Glueck 1959, 218; Mayerson 1959; Evenari *et al.* 1982, 127-147.

antiquity had no soil beds is correct and that given an annual erosion rate of 0.1 mm – 0.2 mm, it would take 200 years to trap 0.5 m – 1 m depth of soil behind a terrace.

Glueck and Evenari *et al.* have proposed from slightly differing standpoints that the purpose of the heaps was to control runoff water. Mayerson rejects Glueck's controlled runoff theory whereby the *teleilat el-anab* deflect water to predetermined goals because it cannot explain the 'flowerpot' and conical heaps. Evenari *et al.* argue that the stone heaps were created to increase the amount of floodwater runoff available because the pounding action of the rain creates a crust on the cleared ground, which in turn increases surface runoff. Although their tests showed an increase in water yield in drought years of c. 40 m^3 by hectare, in wet years this increase was reduced to just 10 m^3 – 20 m^3 per hectare. Mayerson argues against this theory on the basis that it assumes knowledge on the part of the ancient farmer, that it is a massive task for such a reward and that it does not take into account almost entirely stony surfaces.

In Mayerson's opinion the heaps are, as they are named, grape mounds associated with growing vines. On this theory the heaps provide areas of micro-irrigation in which the vines can grow and be watered by hand; ethnographical evidence from Bedouin practices seems to back up this argument comfortably [Fig. 5.32]. Evenari *et al.* have argued against this theory on the basis that cisterns would not have enough capacity to water the vines and that 'the Bedouin is neither an ingenious inventor nor a gifted farmer'. Although the cistern argument may hold some force, the argument concerning the Bedouin farming techniques does not seem to be supported by any concrete evidence. Overall Mayerson's theory seems to be the most compelling solution to these soil and stone heaps, though it, like the others, does not yet explain why three different types were used. It seems possible that they had varying functions, for example planting in flowerpot mounds and directing runoff with ridge mounds, which may explain why no single theory can explain them satisfactorily.

5.8 Discussion and conclusions

Firstly, it is interesting to note the reasonably high occurrence of storage installations integrated into the irrigation systems. Particularly noteworthy is the size and storage capacity of these installations in comparison to those found in urban centres. Whereas the reservoirs in urban centres seem to have comparatively low storage capacities (see Chapter 7.3, Tables 7.2-3) with just 1 reservoir out of 23 with known dimensions having a capacity over 10,000 m^3, 4 of the 5 reservoirs associated with qanat systems had capacities over 10,000 m^3 (if the depth is presumed to be at least 3 m deep). This seems to show a clear concern for storing irrigation water; the consequences of this observation will be discussed in more detail in Chapter 6.3.2.

This analysis of irrigation techniques in the Near East has provided a picture of a densely irrigated rural landscape in places. In addition, it has shown the variety and complexity of the techniques used, each suited to the needs and demands of the local landscape. On a broad scale this can be illustrated schematically [Fig. 5.33], showing that irrigation channels were used in zones distinct from qanats, i.e. irrigation channels in areas with perennial rivers and qanats in the steppe. The different irrigation techniques were restricted by their geographical location, with little or no overlap.

Another important observation that can be made despite the poor dating of the installations is their broad similarities over time (though individual details may change). One wonders, for example, how different the landscape at Auara would have looked if it had been set out a century later. There are only so many ways of irrigating land effectively according to the geologic and topographic circumstances of the land needing to be irrigated. Rather, the variable is the intensity of the application of this technology (see below). One possible exception to this lack of change may be the introduction of qanats to the region.

The techniques outlined above, in particular the field systems, were very similar to those found during the same period in North Africa. Most of the walls recorded during the Libyan Valleys Survey controlled overland flow on hillsides and floods on wadi floors.[75] The walls on the plateaux and wadi sides were oriented obliquely to the hill slope in order to trap surface runoff and feed it down to the wadi floor. On the wadi floor, cross-wadi walls impeded the water, forming small pools or lakes [Fig. 5.34]. Water for consumption

[75] Gilbertson and Hunt 1996, 217.

by people and animals was in some instances directed by plateau and wadi walls to cisterns or caves. One pertinent observation that came out of this work in Libya was that there were recurrent types, patterns and relationships of walls, i.e. the designs of the walls followed a fairly standard series.[76] Furthermore, the major differences were chronological and circumstantial. In the earlier phase of open farming, the channel walls were directed to cisterns. In the later phases of *gsur* farming, a full range of cross-wadi, side and plateau walls and fields were encountered.

In spite of the problems concerned with dating the majority of these installations, some interesting hypotheses do present themselves. The high numbers of irrigation channels in use during the late Roman period suggest that there was a higher level of irrigated agriculture at this time. This may also be supported by the qanat evidence, which showed that they were in relatively common use by this period, as well as the probable upward trend in floodwater farming and the evidence of cistern-fed gardens in monastery settings.

This fits in with an observable peak in the agrarian economy in the late Roman period.[77] Several reasons have been put forward for this upturn. While the single largest landholder in the region was the state (in the form of the fisc or the emperor), the Church also maintained significant areas of land for its ecclesiastical and monastic properties, for example around Dara and Antioch.[78] Monasteries were centres of production and developed marginal areas, hence the cistern-fed gardens noted above.

A growth in rural settlement and population, which had increased throughout the period of Roman rule, was most striking in this period, as attested, for example, by the Dead Cities in the limestone massif of Syria.[79] The amount of settled land in the hinterland seems to have been directly proportional to an increase in urbanisation, for example at Dara, Anasartha and Maurikopolis.[80] In this increasingly crowded landscape agricultural intensification must have been necessary to meet personal needs as well as urban and export demands. We know from literary sources, for example, that grain was frequently sold on

[76] Gilbertson and Hunt 1996, 224.
[77] Decker 2001, 337; Butcher 2003, 139.
[78] Mango 1984, 409; Decker 2001, 39.
[79] Butcher 2003, 140, 146.
[80] Decker 2001, 340.

the open market in cities.[81] In addition, Antioch and Apamea were exporting olive oil.[82] Libanius also sold wine in Cilicia.[83] This phenomenon has been observed elsewhere in the Empire, for example in North Africa and Italy it was noted that an intensification in rural hydraulic infrastructure seemed to go hand in hand with proximity to urban markets.[84]

It has been suggested that this intensification of rural production seems to be at odds with the literary evidence, which emphasised the crushing tax burden in the late Roman period.[85] It seems possible though that it may have been just this tax burden that prompted an increase in agricultural production. The supply of the late Roman army and the *annona militaris* must also have exerted a significant amount of pressure on the production capabilities of the rural landscape. The late Roman army was divided into small legions of c. 1,000 men (unlike the large legions of the principate and early Empire), some of which were mobile field army units (*comitatus*) and some of which were permanently based. By the 4th century AD, with the exception of the *III Cyrenaica* at Bosra, most of the legions had moved to bases in remote areas (Table 5.2).[86] It seems likely that these legions were supplied locally and that the provinces were responsible for soldiers within their borders. Libanius' letters, for example, show that the provision of supplies for the army at Callinicum on the Euphrates and further east in Mesopotamia placed a heavy burden on 4th-century Antioch.[87] In general, Egyptian grain was not used to supply the eastern armies, except under exceptional circumstances.[88]

[81] Julian regulated grain prices in Antioch, which were higher than in Egypt, in AD 362-3. Grain prices were also regulated during the famine of Edessa. The Life of St Spyridon also attests to permanent markets in cities. See Liebeschuetz 1972, 128; Trombley and Watt 2000, 39; Decker 2001, 299; Butcher 2003, 167.
[82] Decker 2001, 341.
[83] Libanius *Ep.* 709; Liebeschuetz 1972, 45; Petit 1955, 305 n. 5.
[84] Wilson 1999, 323.
[85] Liebeschuetz 1972, 73.
[86] Butcher 2003, 414.
[87] Eg Libanius *Ep.* 21 (358); Liebeschuetz 1972, 163.
[88] Josh. Styl. 70; Decker 2001, 302, 304; Liebeschuetz 1972, 76. On Julian supplying Antioch with corn from Egypt in AD362, see Liebeschuetz 1972, 130.

Table 5.2: Bases of late Roman legions in remote areas of the East.

Legion	Base	Province
IV Scythica	Taibe	Syria
XVI Flavia	Sura	Syria
III Gallica	Danaba	Syria
I Illyricorum	Palmyra	Syria
X Fretensis	Aila	Palestine
IV Martia	Betthorus (Lejjun)	Arabia

The locations of large-scale irrigation works and the presence of the late Roman army seem to tally remarkably well. It was noted above, for example, that several of the irrigation channels flowed within the *territoria* of late Roman fortresses such as Barbalissos, Callinicum and Circesium. In addition, there seems to have been a marked tendency for qanats to be employed in the vicinity of military sites. This may be because many of the military frontier sites were in the desert, and so qanats may have been the only viable option. Similar military-based explanations have also been proposed to explain the seeming increase in numbers of field systems in the later Roman periods.[89] This can also be tied to the pattern observed in Chapter 4, where some of the dams were located along the *Strata Diocletiana*. It seems plausible that military labour and engineers would have been employed for a number of these irrigation projects.

This highlights the nature of the impact of a Roman authority on the irrigated landscape of the Near East. While there is no incontrovertible evidence for any technological impact in terms of changes, improvements or additions to the existing methods, it seems that administrative changes and the presence of the late Roman army may have contributed to the intensification of agricultural production and irrigation. In this way we can see a reciprocal relationship between an imposed imperial authority and the existing population. That said it might go too far, or even be naïve, to suggest that the presence of the late Roman army did not prompt negative reactions. Although the authorities may have been content to respect the native knowledge found in the East, the actual effort involved in order to fulfil their requirements must have put considerable strain on the resources available to local populations.

[89] Newson 2002, 260.